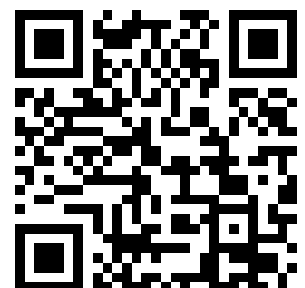

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Computer Sciences and Data Systems

Marston Science

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the National Conference Center in
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NASA

PLANS

- Install and evaluate components at Langley as they become available
- Use ENCOMPASS prototype to examine more advanced features
- Prototype will be used to examine the practical applications of SAGA

Cognitive-Based Analysis of Software Documentation¹

**Elliot Soloway
Associate Professor of Computer Science
and Psychology
Cognition and Programming Project
(CAPP)
Computer Science Department
Yale University
New Haven, CT 06520**

This research was supported in part by the Jet Propulsion Laboratory California Institute of Technology under contract with the National Aeronautics and Space Administration, and by the National Science Foundation grant DCR - 8302382.

¹Presented 11/18/86 by David Littman

TODAY'S TALK

- THE PROBLEM OF DOCUMENTATION IN MAINTENANCE CONTEXT
- SOME OF THE ISSUES WE HAVE STUDIED EMPIRICALLY
- A TASTE OF THE RESULTS OF OUR STUDIES

THE PROBLEM WITH DOCUMENTATION

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OUR APPROACH: THE COGNITIVE PERSPECTIVE

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 - **WHEN TO PRESENT THE INFORMATION?**
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- **AREA 2: EXAMINING THE WHAT & WHEN QUESTIONS**
 - **PROGRAMMERS CONFRONT LARGE PROGRAM (60K LINES)**
 - **1.5 FEET OF DOCUMENTATION**
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MORE WHAT NEXT?

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- **PROBLEM IS HOW TO DOCUMENT THEM?**
 - **TELL WHAT THE ROUTINE DOES**
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- **MAKE STRUCTURE OF DOCUMENTATION EXPLICIT**

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JPL

Chi Lin

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- SLICS
 - SCENARIO OF MODEL APPLICATION
 - INPUTS/OUTPUTS
 - MODEL STRUCTURE
 - EQUATIONS
- ACCOMPLISHMENTS AND FUTURE FOCUS

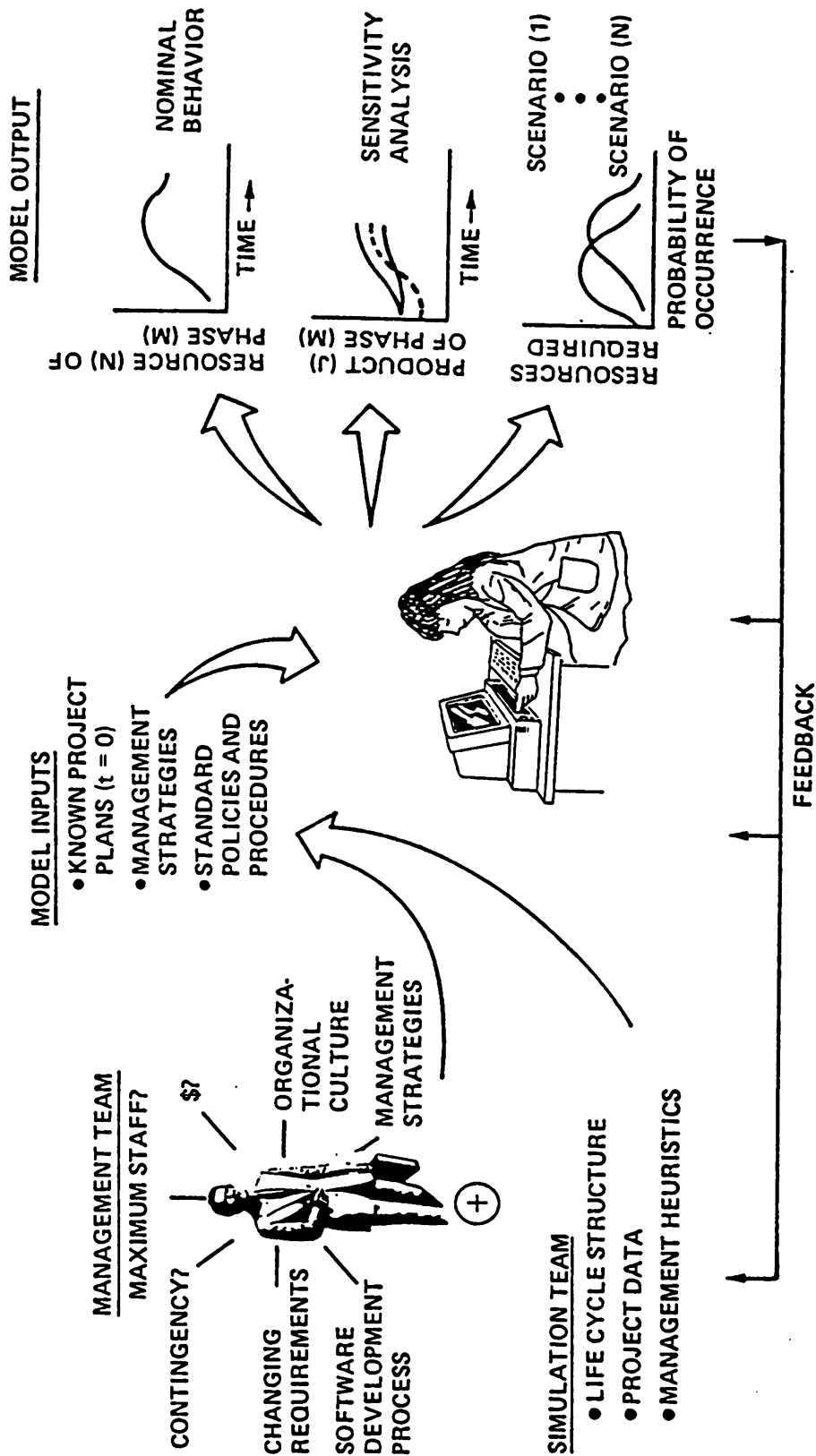
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 - DYNAMIC MODELING
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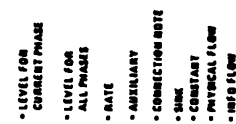
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Chi Lin

TASK PARTICIPANTS

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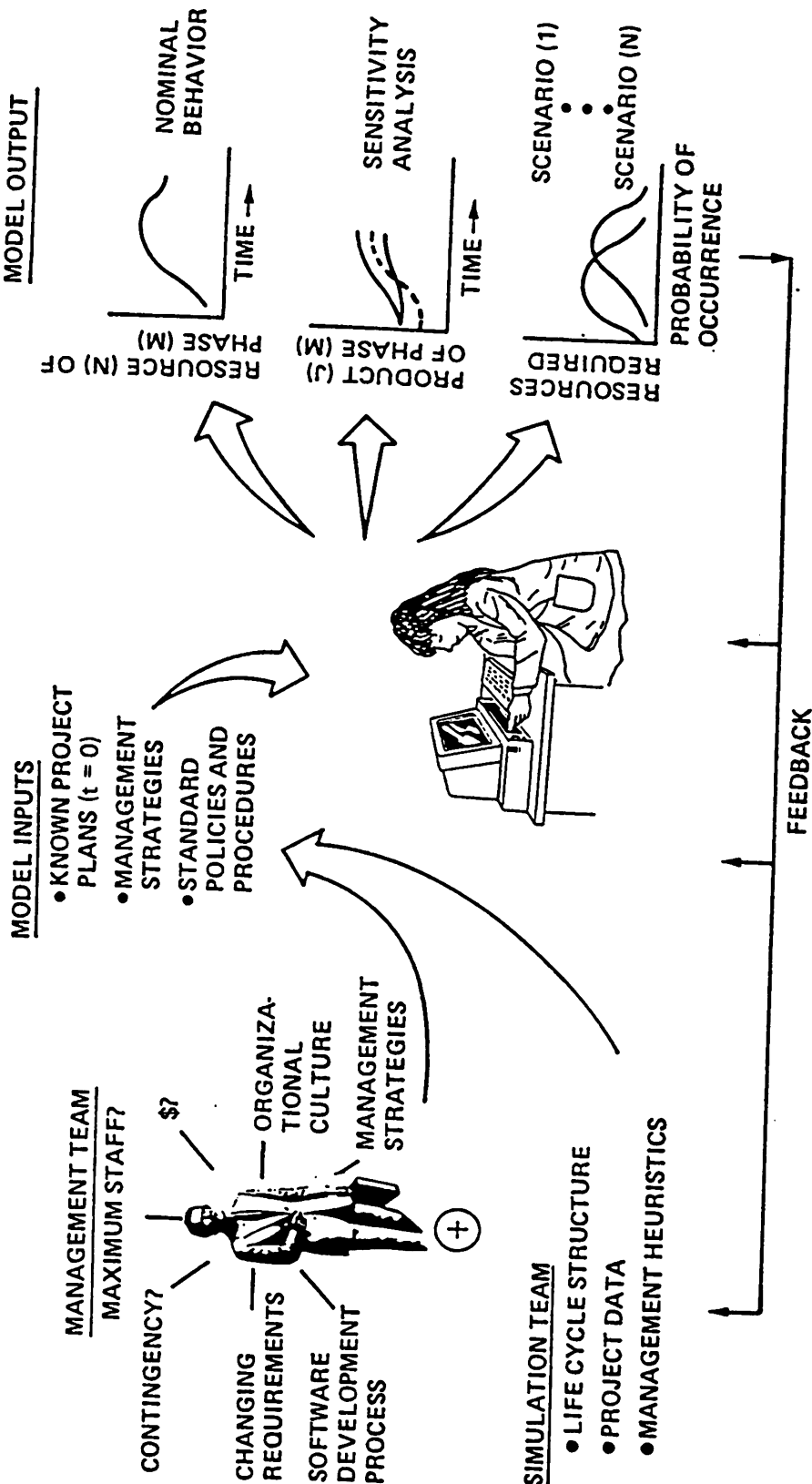
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PROVIDE SOFTWARE MANAGERS WITH QUALITY
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PAYOFF
DYNAMIC CONTROL OF LARGE
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$$\frac{d}{dt} \text{WORKLOAD}_i = \text{NEWWORK}_i + \sum_i^n \text{REWORK}_i - \text{PRODUCTION}_i$$

INITIAL VALUE WORKLOAD_i (t = 0) = 0

$$\text{NEWWORK}_i = \begin{cases} 0 & \text{WHEN STATUS}_{(i-1)} \leq X\% \\ \text{PULSE (EST. WORKLOAD}_i) & \text{OTHERWISE} \end{cases}$$

REWORK_i = DELAY_i (ERROR FOUND)_i

PRODUCTION_i = S_i P_i P_γ P_β . . . P_σ

S_i : STAFF SIZE

P_i : STAFF PRODUCTIVITY UNDER NOMINAL CONDITIONS

E.G., P_γ : SCHEDULE PRESSURE FACTOR

$$P_\gamma = \begin{cases} 1 & \text{WHEN PROJECT STATUS IS NORMAL} \\ 0 < \text{HEURISTIC TABLE (STATUS}_i) < 1 & \text{OTHERWISE} \end{cases}$$

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SOFTWARE ENGINEERING WITH REUSABLE COMPONENTS TASK

M. J. Steinbacher

JPL

November 18, 1986

**Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California**

JPL SOFTWARE ENGINEERING WITH COMPONENTS

- Components include source code, design, test cases, and other software products
- Purpose of this task is to use past and current efforts within DoD (STARS, SEI, ---), NASA, and Industry to investigate software engineering with components as a means of improving quality and productivity while decreasing life cycle costs

JPL SOFTWARE ENGINEERING WITH COMPONENTS

Key technology areas

- **Guidelines for the development of/evaluation and certification criteria for components**
- **Techniques and methods for the development of software systems out of components, and software systems partitioning and design techniques and methods to facilitate the identification and development of reusable components**
- **Library technology advancement (and interface with)**

JPL APPROACH TO TECHNOLOGY INVESTIGATION

For component technology

- **Input**
 - **STARS — Application Area: reusability guidebook and CAMP project**
 - **STARS — Measurement Area metrics work**
 - **GSFC — SEL metrics work and Ada guidelines**
 - **Yale studies, reports and guidelines**
 - **DoD — Ada repository**
 - **U of H/JSC, other Centers, and Industry reports**
 - **JPL — Reports and Ada components**
- **Process**
 - **Develop an evaluation criterion from above input; collect existing components and evaluate against criteria; update criteria and produce a guideline for creating reusable components**
- **Products**
 - **Evaluation criteria; development guidelines; a repository of “evaluated” components**

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APPROACH TO TECHNOLOGY INVESTIGATION (Cont'd)

For software system technology

- **Input**
 - **Components, experience, etc. — from component work**
 - **STARS, Application Area — CAMP Project Experiences**
 - **SEI — Process Architecture Project and Reuse Project**
 - **Yale studies**
 - **Design/Partitioning of several current software systems**
- **Process**
 - **Using components available, investigate various approaches to develop a software system out of components. Investigate how different design/partitioning approaches affect ability to identify and locate parts. Compare findings to design/partitioning of several existing systems**

JPL

APPROACH TO TECHNOLOGY INVESTIGATION (Cont'd)

Long term

- **Develop a strategy for the development of software systems using components and a "software architect assistant"**

SOFTWARE ENGINEERING WITH REUSABLE COMPONENTS
ATTACHMENT

JPL

KEY TECHNOLOGY AREAS

Component Technology Issues Examples:

- o What is the criteria for determining "reusability" of a component?
 - reliability, maintainability, other "ility" measures/metrics
 - encapsulation
 - commonality with similar or different application areas
 - documentation and other related software products
- o What are the behavioral/context/environmental factors?
 - side effects or singularities
 - target, word size, etc. constraints
 - operating conditions constraints
- o What are attributes for determining the confidence factor (trust level) of a component?
 - what other information do users need/want to know in order to "trust" a component -- related to cognitive process studies and the need to know some "why's" and "what's", not just "how's"
- o What are the guidelines for developing reusable components?
 - use of data abstraction, generics, typing mechanisms
 - encapsulation and packaging
 - data management and other hardware/operating system considerations
 - trade between generality and specificity
 - information and related data products needed to support reuse

Software System Technology Issues Examples:

- o What is the affect on the requirements and design phases when component reuse is desired?
 - requirements/design phases iteration and interaction
 - affect on design phases when both requirements and parts are input
- o What approaches/techniques can be employed during the design phase to incorporate the proper balance of systems-driven and parts-driven strategies?

Learning the Behavior of Software Systems
From Executable Specifications

Christian Wild

Associate Professor
Old Dominion University
Norfolk, VA

* Supported by NASA Grant 1-439

Objective

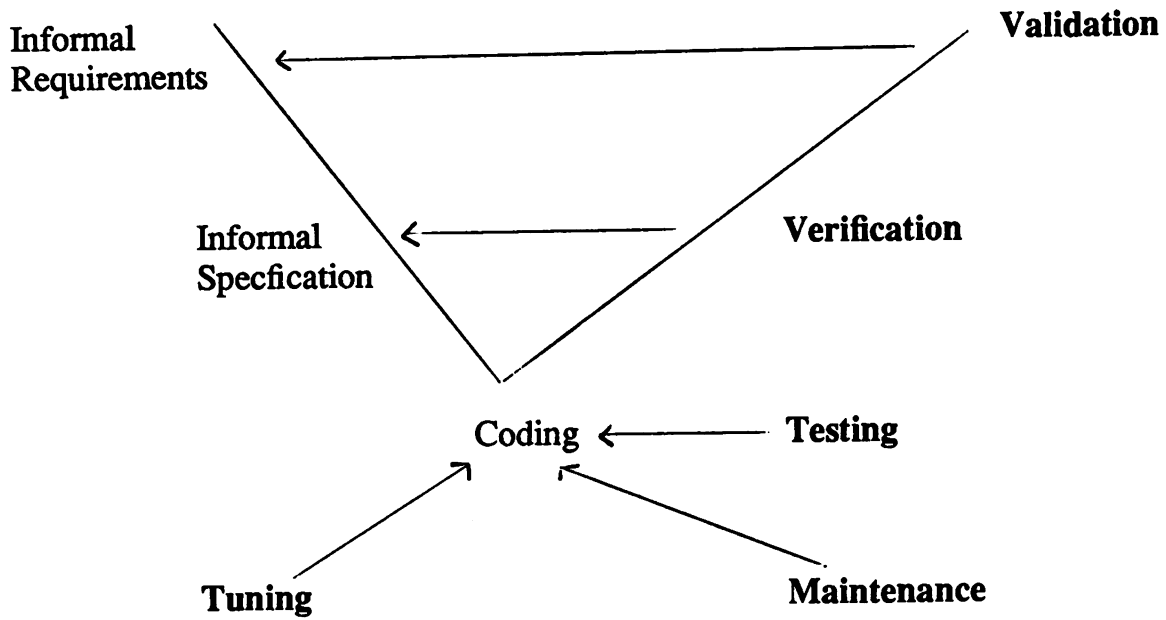
Significantly Increase the Reliability and Robustness of Software Systems

- **Reliability - Development**
- **Robustness - Operation**

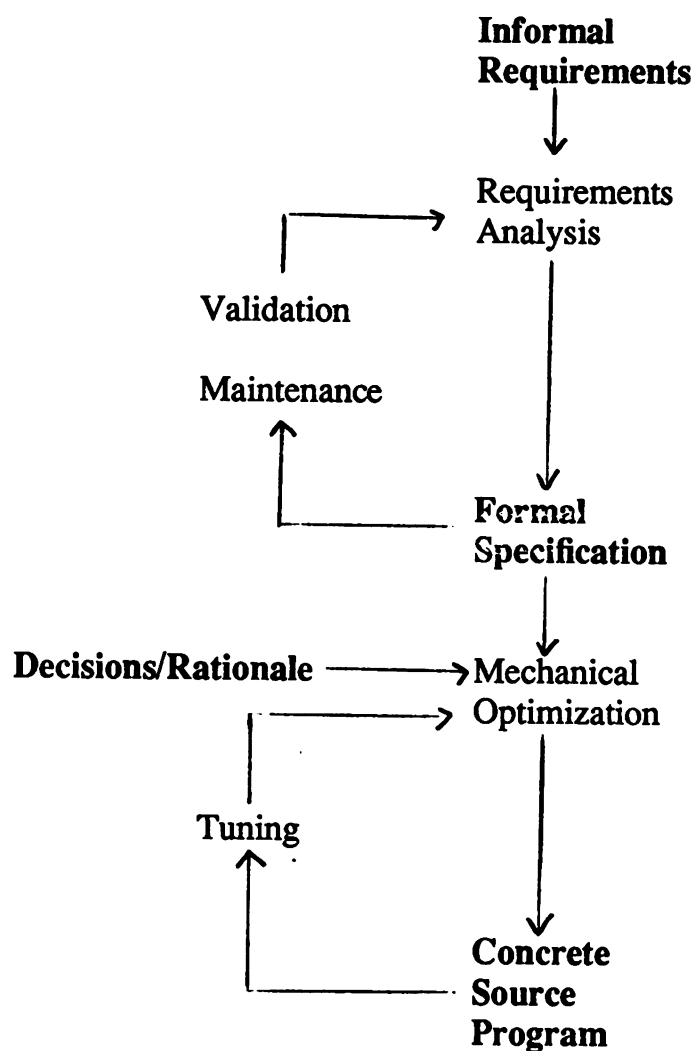
Statement of Problem

- Complexity increasing
- Criticality increasing
- First implies automation
- Second implies formal analysis
- which in turn implies formal description
- Orders of magnitude increase in reliability cannot be met by traditional software engineering approaches.
- more than just integrated tools at the current level of sophistication.
(not smart editors and command interpreters)

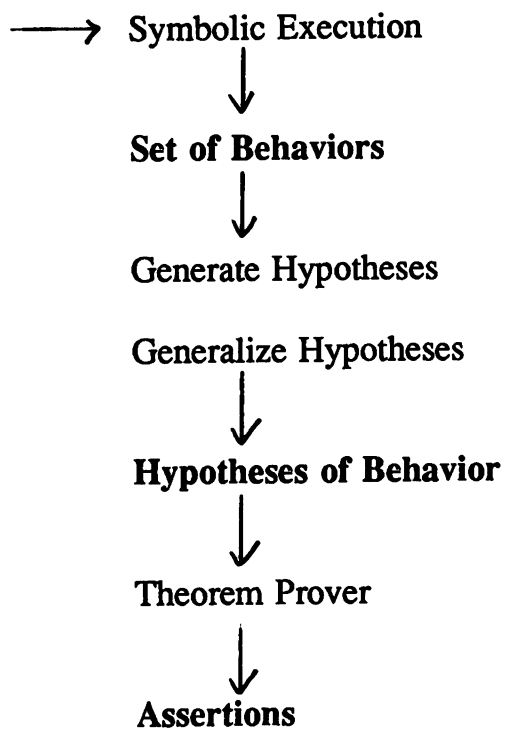
Current Software Development Paradigm



Automation Based Software Development Paradigm



- Slide adapted from ISI at USC



Supporting Technologies

- **Formal Specification Languages**
- **Program Verification**
- **Automatic Programming**
- **Rapid Prototyping**
- **Machine Learning**
- **Automated Reasoning**
- **Knowledge-Based Systems.**
- **Software Fault Tolerance**

Definitions

- **Behavior** - Result of applying a function
- **Formal Specification** - Implicitly defines behavior
- **Set of Behaviors** - Explicitly defines behavior
- **State** - Sequence of function calls which generated a data object
- **Canonical Form** - Simplest sequence of function calls which exhibits equivalent behavior

Formal Specification for Queues

Type Queue(Integer)

SYNTAX

Newq	-> Queue
Addq(Queue,Integer)	-> Queue
Deleteq(Queue)	-> Queue
Frontq(Queue)	-> Integer \cup {error}
Isempyq(Queue)	-> Boolean

SEMANTICS

For all q : Queue; i : integer Let

- | | | |
|----|--------------------|--|
| 1) | Isempyq(Newq) | = True |
| 2) | Isempyq(Addq(q,i)) | = False |
| 3) | Frontq(Newq) | = error |
| 4) | Frontq(Addq(q,i)) | = If Isempyq(q) then i
else Frontq(q) |
| 5) | Deleteq(Newq) | = Newq |
| 6) | Deleteq(Addq(q,i)) | = If Isempyq(q) then Newq
else Addq>Deleteq(q),i) |

End Queue

Examples of Behavior

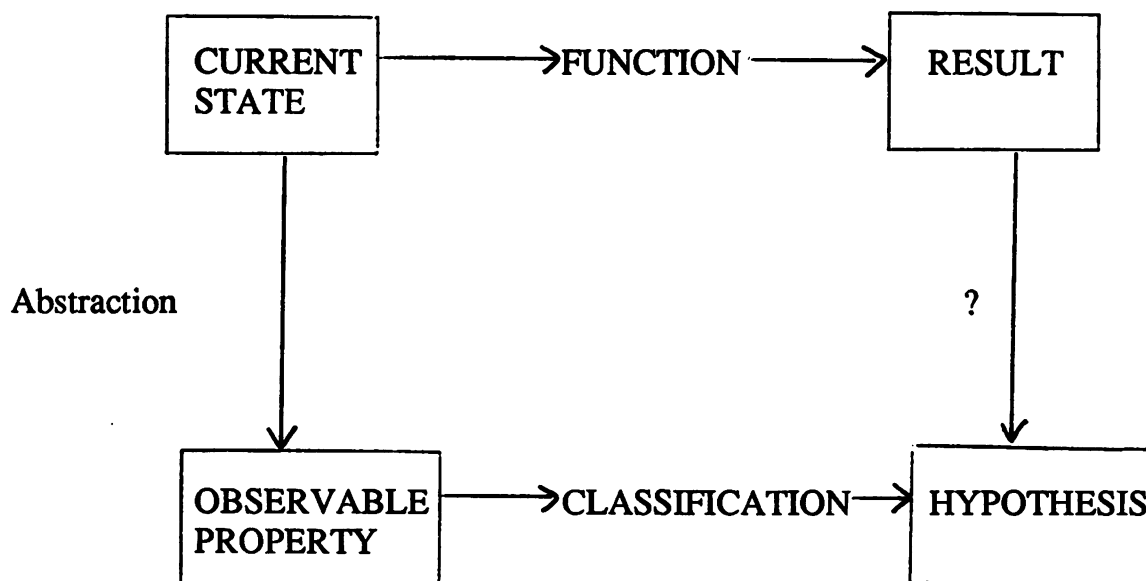
Generators:

$$\text{ADDQ}(\text{ADDQ}(\text{NEWQ}, I_1), I_2)$$
$$\text{DELETEQ}(\text{ADDQ}(\text{ADDQ}(\text{NEWQ}, I_1), I_2)) = \text{ADDQ}(\text{NEWQ}, I_2)$$

Behaviors:

$$\text{ISEMPTYQ}(\text{DELETEQ}(\text{ADDQ}(\text{ADDQ}(\text{NEWQ}, I_1), I_2))) = \text{False}$$
$$\text{FRONTQ}(\text{DELETEQ}(\text{ADDQ}(\text{ADDQ}(\text{NEWQ}, I_1), I_2))) = I_2$$

Learning Hypothesis of Behavior



Hypotheses are of the form:

$$\text{FUNCTION}(X) = \text{RESULT} ? A_F(X) \in \{\text{PVs}\}$$

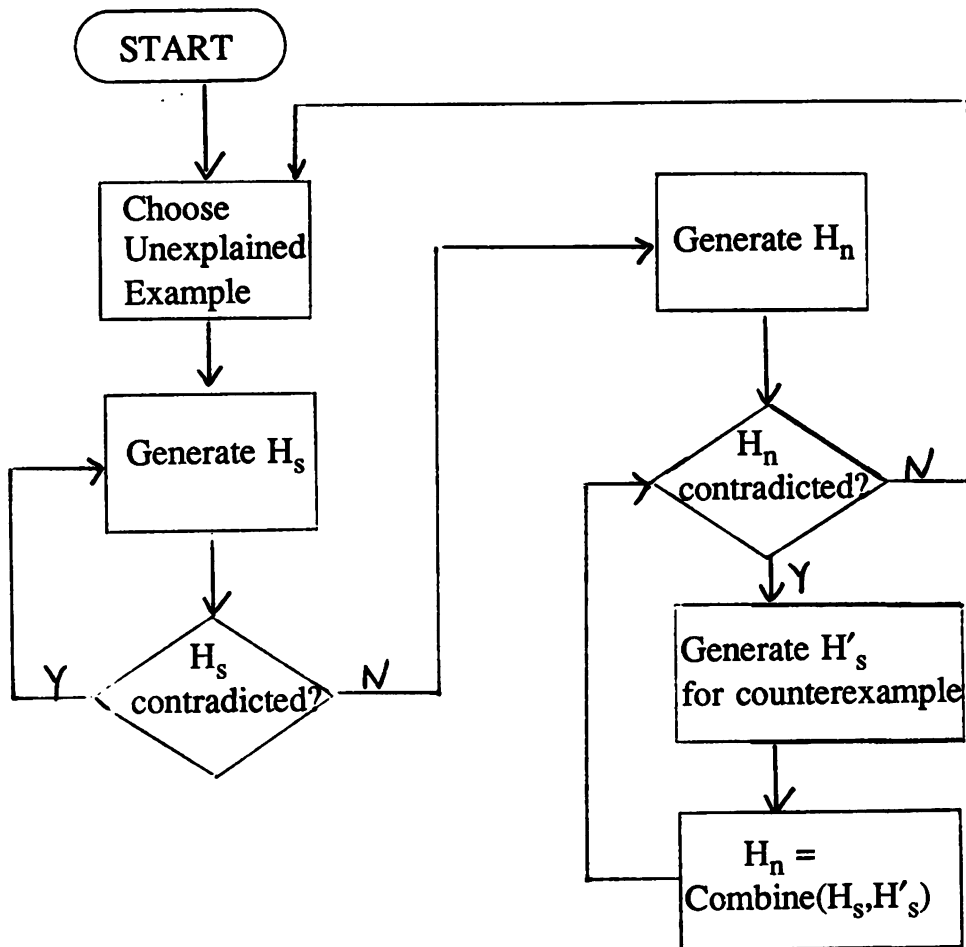
Where ? is:

IF - sufficient

ONLY IF - necessary

IFF - necessary and sufficient

Learning Algorithm



Nomenclature

- The AF is of the form #X, where X is A (D or N) if the AF counts the number of *Addqs* (*Deleteqs* or *Newqs*) in the WFF.
- AFs on the canonical form will be designated by adding a prime (').
- AFs which count events occurring before a key event are denoted by a subscript of *pre//_n*, where *I_n* is the item added at the key event.
- For events occurring after the key event the subscript *post//_n* is used.

$\text{Deleteq}(\text{Addq}(\text{Addq}(\text{Newq}, I_1), I_2)) : (\#A=2, \#A'=1, \#N=1, \#A_{pre//2}=1, \#A_{post//1}=1)$

$\text{Iseptyq}(\text{Newq}) = \text{T} : (\#N=1)$

$H1, \quad \text{Iseptyq}(Q) = \text{T} \text{ if } \#N \in \{1\}$

$\text{Iseptyq}(\text{Addq}(\text{Newq}, I_1)) = \text{F} : (\#A'=1, \#N=1, \#A=1)$

DIFF : $\{\#A', \#A\}$

OUT : $\{\#N\}$

$H2, \quad \text{Iseptyq}(Q) = \text{T} \text{ if } \#A' \in \{0\}$

$H2_n \quad \text{Iseptyq}(Q) = \text{T} \text{ only if } \#A' \in \{0\}$

$\text{Iemptyq}(\text{Addq}(\text{Newq}, I_1)) = \text{F} : (\#A'=1, \#N=1, \#A=1)$

$H3_s) \quad \text{Iemptyq}(Q) = \text{F} \text{ if } \#A' \text{ member-of } \{1\}$

$H3_n) \quad \text{Iemptyq}(Q) = \text{F} \text{ only if } \#A' \text{ member-of } \{1\}$

$\text{Iemptyq}(\text{Addq}(\text{Addq}(\text{Newq}, I_1), I_2)) = \text{F} : (\#A'=2)$

$H4_s) \quad \text{Iemptyq}(Q) = \text{F} \text{ if } \#A' \text{ member-of } \{2\}$

$H5_s) \quad \text{Iemptyq}(Q) = \text{F} \text{ if } \#A' \text{ member-of } \{1,2\}$

$H5_n) \quad \text{Iemptyq}(Q) = \text{F} \text{ only if } \#A' \text{ member-of } \{1,2\}$

$H6) \quad \text{Iemptyq}(Q) = \text{F} \text{ iff } \#A' \text{ member-of } \{1..\infty\}$

Program Synthesis for *Iemptyq*

**IF #A' = 0 THEN TRUE
ELSE FALSE**

Demands which this behavior places on generators:

NEWQ:	Set #A' to 0
ADDQ:	Increment #A' by 1
DELETEQ:	Decrement #A' by 1

More Complicated Result

Raw Output:

H10) $\text{Frontq}(Q) = I_2$ if $(\#A', \#A_{\text{post}/I_2}) \in \{(1,0), (2,1), (3,2), \dots\}$

H11) $\text{Frontq}(Q) = I_2$ if $(\#D_{\text{post}/I_2}, \#A'_{\text{pre}/I_2}) \in \{(0,0), (1,1)\}$

H12) $\text{Frontq}(Q) = I_2$ if $(\#A, \#A') \in \{(2,1), (3,2), (4,3), \dots\}$

Generalized Output:

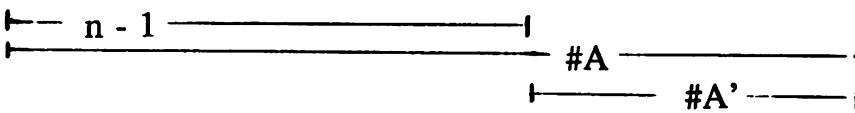
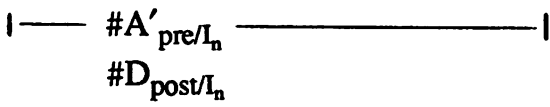
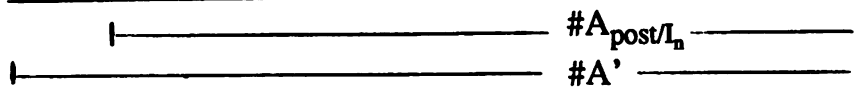
H10'') $\text{Frontq}(Q) = I_n$ iff $(\#A' - \#A_{\text{post}/I_n} = 1)$

H11'') $\text{Frontq}(Q) = I_n$ iff $(\#D_{\text{post}/I_n} - \#A'_{\text{pre}/I_n} = 0)$

H12'') $\text{Frontq}(Q) = I_n$ iff $(\#A - \#A' = n-1)$

<- Front

Back ->



Conclusions

- **Machine Analysis of Executable Specifications:**
 - **Program Synthesis**
 - **Automated Test Case Generation**
 - **Assertion Generation for Run-Time Monitoring**
 - **Feedback to Requirements Analysis**
- **Symbiotic Interaction:**
 - **Machine Learning**
 - **Symbolic Execution**
 - **Theorem Proving**



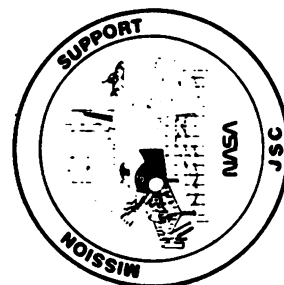
NASA MISSION SUPPORT DIRECTORATE **JSC**

JSC SPONSORED RESEARCH ACTIVITY UNIVERSITY OF HOUSTON AT CLEAR LAKE

NOVEMBER 18, 1986
STEVE GORMAN / JSC FR12

NASA
National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas



JSC FORM 947 (JUNE 86)



MSD

OUTLINE

1. PRE RICIS (MAY 1986) UHCL RESEARCH ACTIVITY
2. FORMATION OF RICIS COOPERATIVE AGREEMENT
3. RICIS CHARTER - GENERAL AREAS OF RESEARCH
4. ESTABLISHED TASKS
5. PLANNED ACTIVITY
6. SUMMARY AND DISCUSSION



PRE RICIS UHCL RESEARCH ACTIVITY

- NUMEROUS TASKS AT UHCL
 - Ada BETA TEST SITE
 - DATA BASE STUDIES
 - ARTIFICIAL INTELLIGENCE STUDIES
- NO CENTRAL COORDINATION
- MANY PROBLEMS AROSE IN MANAGING THE CONTRACTS
 - FUNDING LIMITS EXCEEDED
 - SOLE SOURCE JUSTIFICATIONS ETC.
 - COSTLY AND TIME CONSUMING PAPER MILL
- PERCEPTION BY JSC COMMUNITY THAT THE SPACE CENTER AND THE UNIVERSITY SHOULD WORK MORE CLOSELY TOGETHER



THE RESEARCH INSTITUTE FOR COMPUTING AND INFORMATION SYSTEMS

- "TOM AND JERRY" ACCORDS SIGNED IN 1983 (TOM STAUFFER, UHCL AND JERRY GRIFFEN, JSC)
- TASK FORCE FORMED TO EXPLORE POTENTIAL AREAS OF COOPERATION
- RICIS CONCEPT GREW OUT OF TASK FORCE ACTIVITIES
- COOPERATIVE AGREEMENT BETWEEN NASA/JSC AND THE UNIVERSITY OF HOUSTON AT CLEAR LAKE
- ESTABLISHED MAY 1986
- TO BE RENEWED YEARLY
- ACTIVE UHCL RESEARCH CONTRACTS WERE FOLDED INTO RICIS
- GOAL:

TO IDENTIFY, DEVELOP, APPLY AND EVALUATE ADVANCEMENTS IN COMPUTING AND INFORMATION TECHNOLOGY REQUIRED IN THE CONDUCT OF NASA/JSC'S VARIOUS MISSIONS

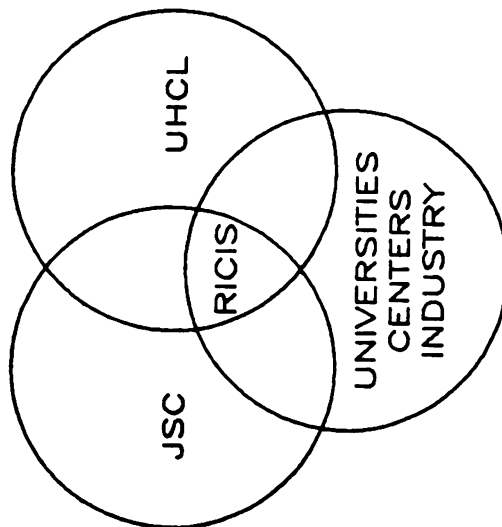


GENERAL AREAS OF RESEARCH

- COMPUTER SYSTEMS AND SOFTWARE ENGINEERING
- ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS
- MATHEMATICAL AND STATISTICAL ANALYSIS
- INFORMATION MANAGEMENT
- EDUCATION AND TRAINING



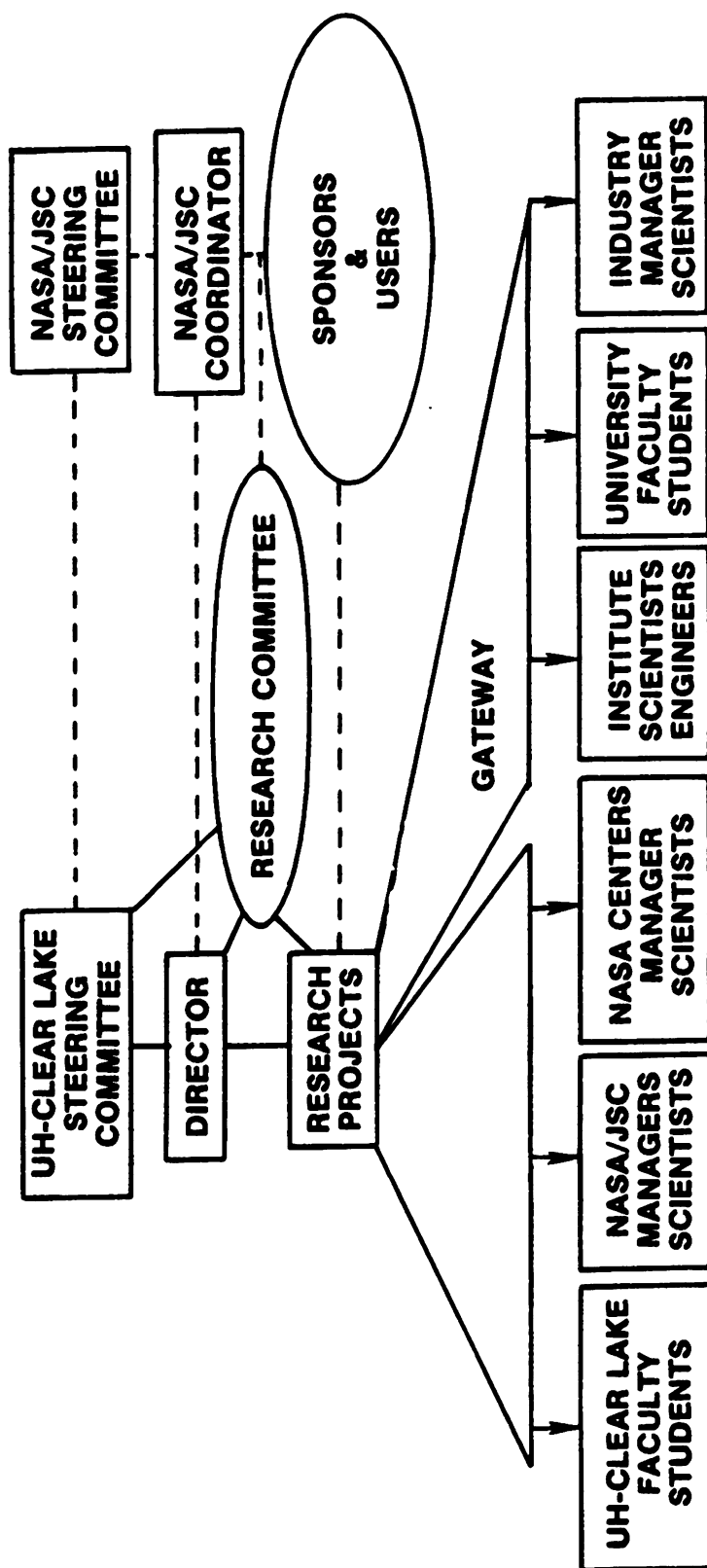
RICIS PARTICIPANTS



UNIVERSITY OF HOUSTON AT CLEAR LAKE
NASA/JSC
RESEARCH INSTITUTES AND CENTERS
INDUSTRY
OTHER UNIVERSITIES AND NASA CENTERS

RESEARCH INSTITUTE for COMPUTING and INFORMATION SYSTEMS

MANAGEMENT STRUCTURE





NASA MISSION SUPPORT DIRECTORATE JSC

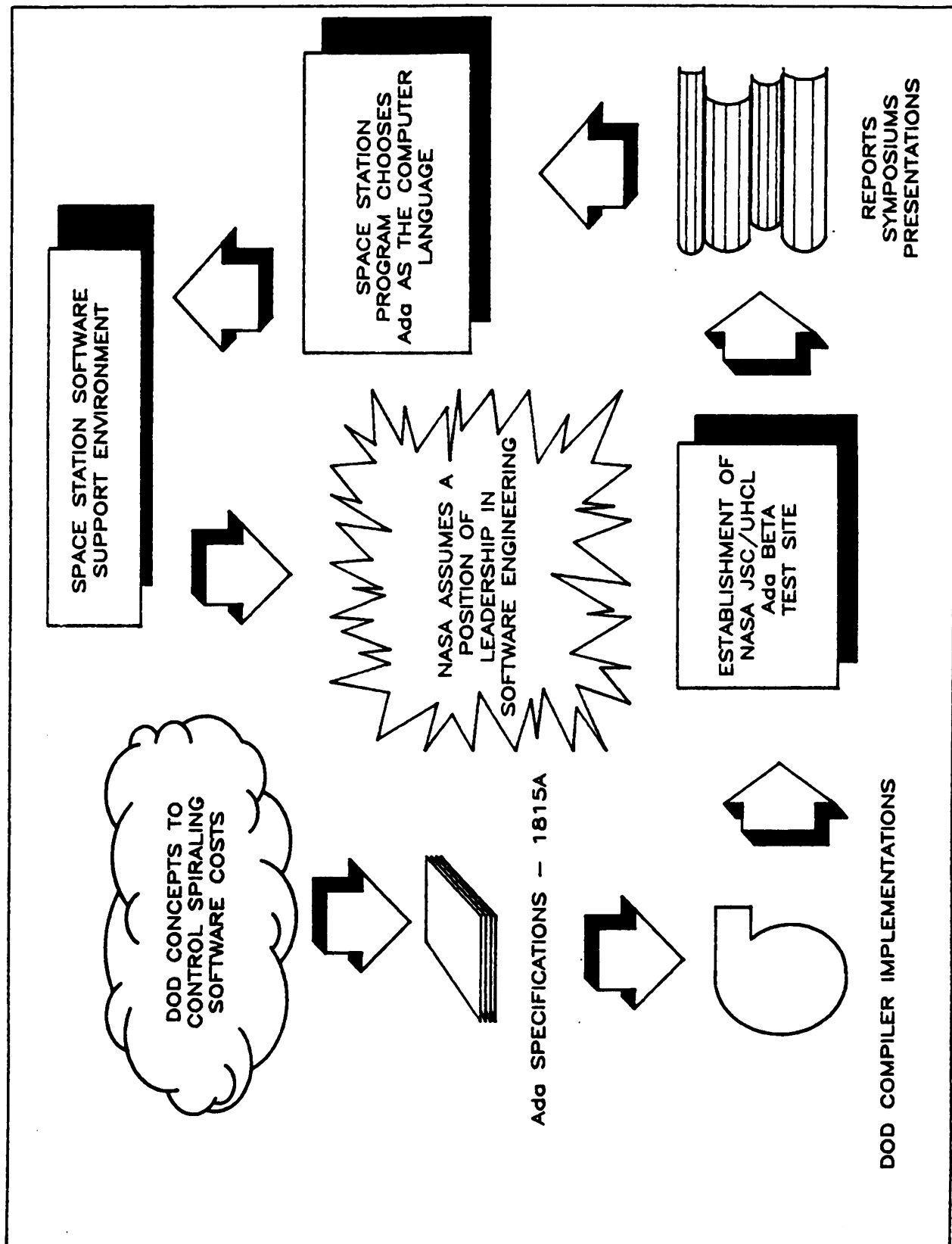
ESTABLISHED TASKS **COMPUTER SYSTEMS AND SOFTWARE ENGINEERING**

- Ada BETA TEST SITE
- JOINT NASA/JSC SOFTWARE ENGINEERING RESEARCH CENTER (SERC)
- DEVELOPMENT OF A PROOF-OF-CONCEPT PROTOTYPE OF THE CLEAR LAKE MODEL FOR Ada RUN TIME SUPPORT ENVIRONMENTS
- CONVERSION OF STATE-OF-THE-ART EXPERT SYSTEM SHELL (ART) TO Ada
- BENCHMARKING Ada ON EMBEDDED COMPUTER SYSTEMS
- Ada RELATED INFORMATION DATABASE
- DEVELOPMENT OF DMS TESTBED USERS MANUAL
- SUPPORT TO NASA AND SERC ON Ada RELATED BOARDS AND COMMITTEES



Ada BETA TEST SITE

- RTOP ACTIVITY - NOW COMPLETE, FUNDED 1983 - 1986
- ACCOMPLISHMENTS:
 - TECHNOLOGY TRANSFER - STATION CHOOSES Ada
 - SUCCESSFUL SYMPOSIUMS
 - MINI-SYMPIOSIUMS, ATOP CONTRACTORS & OTHERS
 - FIRST INTERNATIONAL CONFERENCE ON Ada PROGRAMMING
 - APPLICATIONS FOR THE SPACE STATION
 - MINIMUM APSE TOOLSET ANALYSIS
 - BENCHMARKING OF Ada IMPLEMENTATIONS
 - INFLUENCE ON HIGH Ada COUNCILS AND COMMITTEES
 - SIGAda Ada RUN TIME ENVIRONMENT WORKING GROUP
 - CAIS WORKING GROUP
 - Ada BOARD
 - KERNAL INTERFACE TEAM (KIT)
 - ESTABLISHMENT OF SIMTEL LIBRARY AT JSC AND UHCL
 - EXTENSIVE PARTICIPATION IN ATOP ACTIVITY BY THE AEROSPACE AND COMPUTING COMMUNITY
- UHCL CONTACT: DR. CHARLES MCKAY





NASA JSC/UHCL SOFTWARE ENGINEERING RESEARCH CENTER

- FOLLOW ON TO THE Ada BETA TEST SITE RTOP
- EXPAND FOCUS TO COVER ENTIRE SOFTWARE LIFE CYCLE
 - DOD 2167 MODEL AS A STARTING POINT
 - SEEK TECHNOLOGY TRANSFER IN:
 - REQUIREMENTS ANALYSIS
 - DESIGN
 - CODE
 - VERIFICATION AND VALIDATION
 - SUSTAINING ENGINEERING
 - SYSTEM RELIABILITY AND QUALITY ASSURANCE
 - COMPUTER SYSTEM SECURITY
- PARTICULAR EMPHASIS ON DISTRIBUTED COMPUTING ISSUES
- AFFILIATION WITH OTHER CENTERS AND INSTITUTES
 - SOFTWARE ENGINEERING INSTITUTE
 - SDI TESTBED AT COLORADO SPRINGS
 - Ada RELATED WORKING GROUPS, ARTWG, KIT (ETC.)
 - OTHERS AS DIRECTED
- SHOWCASE STATE-OF-THE-ART SOFTWARE SUPPORT ENVIRONMENT
- ASSIST NASA IN REPRESENTATION ON BOARDS AND COMMITTEES
- UHCL CONTACT: DR. CHARLES MCKAY



**PROOF-OF-CONCEPT PROTOTYPE OF THE CLEAR LAKE MODEL FOR Ada
RUN TIME SUPPORT ENVIRONMENTS**

- ESTABLISH DISTRIBUTED Ada TESTBED UTILIZING THE EXISTING DMS TESTBED RESOURCES
 - DG MV8000 AS HOST
 - THREE DG MV2000 WORKSTATIONS AS "TARGETS"
 - OFF THE SHELF ETHERNET AS NETWORK
 - ROLM/DG Ada DEVELOPMENT SYSTEM
 - ROLM ARTS REAL TIME OPERATING SYSTEM
 - ROLM Ada RUN TIME ENVIRONMENT
 - ROLM CROSS COM TEST MANAGEMENT SOFTWARE
- ANALYZE AND PROTOTYPE THE EXTENDED Ada RUN TIME ENVIRONMENT IN THE AREAS OF:
 - COMMAND LANGUAGE INTERFACE
 - NON FUNCTIONAL REQUIREMENTS
 - SYMBOLIC DEBUGGING
 - CONSULTING AND DIAGNOSTIC DEMONS
 - SIM BUFFER FUNCTIONALITY
 - HOST/TARGET FUNCTIONALY REQUIREMENTS SPECIFIC TO THE DISTRIBUTED COMPUTER PROBLEM
- UHCL CONTACT: DR. CHARLES MCKAY



CONVERSION OF ART TO Ada

- INVESTIGATE THE PROBLEMS TO BE OVERCOME IN CONVERTING AN EXISTING STATE-OF-THE-ART EXPERT SYSTEM DEVELOPMENT TOOL TO Ada
- PHASE 1: DESIGN THE CONVERSION TO Ada OF THE "AUTOMATED REASONING TOOL" OR ART (A PRODUCT OF THE INFERENCE CORPORATION)
 - CURRENTLY WRITTEN IN INFERENCE LISP
 - ANALYSIS AND PRELIMINARY DESIGN
 - INITIAL PROTOTYPING
 - MANAGEMENT PLAN
- PHASE 2: DEVELOP AND DELIVER ART IN Ada
- UHCL CONTACT: DR. CHARLES MCKAY



BENCHMARKING Ada ON EMBEDDED COMPUTER SYSTEMS

- ASSESS THE QUALITY AND MATURITY OF Ada DEVELOPMENT SYSTEMS AND Ada RUN-TIME ENVIRONMENTS
- DEVELOP AND COLLECT A SET OF BENCHMARK PROGRAMS
- WITH ASSISTANCE FROM CSDL PERSONNEL RUN THE BENCHMARKS AND REPORT ON FINDINGS
 - MICROVAX / ELN
 - DG MV8000 (ROLM HAWK EMULATION) / ROLM ARTS
 - AN/YUK 44 WITH SOFTECH Ada RUNTIME ENVIRONMENT



Ada RELATED INFORMATION DATABASE

- TO BE AN ON-LINE UTILITY AVAILABLE TO ALL IN THE Ada/SOFTWARE ENGINEERING COMMUNITY
- ORACLE BASED
- LOCATED EITHER ON A CIN OR UHCL MAINFRAME
- HIGHLY USER FRIENDLY - EXTENSIVE MENUS AND REPORT FORMATS AVAILABLE
- EDUCATION AND TRAINING RESOURCES
- Ada RELATED BOOKS AND PAPERS
- DESCRIPTIONS AND INFORMATION ON CURRENT PROJECTS WHERE Ada IS BEING USED
- DESCRIPTION OF REUSABLE Ada COMPONENTS
- UHCL CONTACT: DR. ANTHONY LEKKOS



DEVELOPMENT OF DMS TESTBED USERS MANUAL

- CRITIQUE AND ANALYSIS OF EXISTING TESTBED USERS MANUAL
 - Ada PERSPECTIVE
 - SOFTWARE ENGINEERING PERSPECTIVE
- PROVIDE OVER-ALL ANALYSIS
- PROVIDE SPECIFIC REVISIONS FOR SECTIONS ON:
 - NETWORK COMMUNICATIONS
 - DATA ACQUISITION AND DISTRIBUTION
 - FILE MANAGEMENT
 - DATABASE MANAGEMENT
- UHCL CONTACT: DR. CHARLES MCKAY



Ada BETA TEST TEAM SITE SUPPORT

- OBJECTIVE: TO UNDERSTAND AND, WHERE APPROPRIATE, INFLUENCE THE IMPROTANT EVOLVING Ada STANDARDS, GUIDELINES, AND POLICIES SO THAT THEY WILL REFLECT THE BEST INTEREST OF THE SPACE STATION PROGRAM
- INTERFACE WITH FOLLOWING ORGANIZATIONS:
 - Ada BOARD
 - KERNAL INTERFACE TEAM
 - COMMON APSE INTERFACE SET (CAIS) WORKING GROUPS
 - Ada RUNTIME WORKING GROUP
 - Ada ANSI STANDARDS COMMITTEE
 - ISO Ada WORKING GROUP #9
- UHCL CONTACT: DR. CHARLES MCKAY



ESTABLISHED TASKS - ARTIFICIAL INTELLIGENCE

- COMMUNICATION AND TRACKING EXPERT SYSTEM STUDY, PHASE I
- ANALYZE THE USE OF EXPERT SYSTEM TECHNIQUES FOR CONFIGURATION AND RECONFIGURATION OF THE SPACE STATION COMMUNICATIONS AND TRACKING SYSTEM
 - ANTENNA TRACKING AND POINTING
 - TV CAMERA POINTING
 - MONITORING AND RECORDING INCLUDING OBSCURATION CONSIDERATIONS
 - AUDIO NETWORK STRUCTURE
 - HISTORICAL DATABASE MANAGEMENT
- UHCL CONTACT: DR. T.F. LEIBFRIED



ESTABLISHED TASKS - EDUCATION AND TRAINING

- SOFTWARE ENGINEERING AND Ada TRAINING
- DESIGN AND IMPLEMENT A PROTOTYPE COURSE FOR UPPER LEVEL MANAGERS ON Ada AND SOFTWARE ENGINEERING (APPX. A HALF DAY)
- ESTABLISH AND MAINTAIN A DATABASE OF SOFTWARE ENGINEERING AND Ada TRAINING AVAILABLE NATIONALLY
- ESTABLISH AND MAINTAIN A DATABASE OF EXPERT RESOURCES IN Ada AND SOFTWARE ENGINEERING AVAILABLE NATIONALLY
- PERFORM AND PUBLISH A MARKET SURVEY OF JSC/CONTRACTOR TRAINING NEEDS IN SOFTWARE ENGINEERING
- DEVELOP AND MAINTAIN A COST-BENEFIT ANALYSIS FOR THE TRAINING OPTIONS IN THE DATABASE
- DEVELOP AND MAINTAIN A STRATEGIC PLAN FOR DELIVERING SOFTWARE ENGINEERING TRAINING TO THE JSC COMMUNITY
- DEVELOP NEW COURSE OFFERINGS AS DIRECTED
- UHCL CONTACT: DR. GLENN FREEDMAN



ESTABLISHED TASKS - INFORMATION MANAGEMENT

- SPACE MARKET MODEL DEVELOPMENT PROGRAM
- CLEAR LAKE AREA COMPUTER CAPABILITY SURVEY



SPACE MARKET MODEL DEVELOPMENT PROGRAM

- PROVIDE AN INFORMATION SERVICE WHICH MONITORS THE EMERGING SPACE MARKET
- PRELIMINARY PRODUCT DEFINITION
- ECONOMIC MODEL OF THE CORE SPACE MARKETS
- FRAMEWORK FOR COLLECTING DATA ON FUTURE SPACE MARKETS
- INTERFACING WITH OTHER INFORMATION SERVICES HAVING DATA ON SPACE MARKETS
- UHCL CONTACT: DR. PETER BISHOP



CLEAR LAKE AREA COMPUTER CAPABILITY SURVEY

- CONDUCT CENSUS OF CLEAR LAKE AREA COMPUTER CAPABILITIES
- AREAS COVERED:
 - HARDWARE
 - SOFTWARE
 - PERSONNEL
 - INSTITUTIONAL AND RESEARCH DIMENSIONS
- ESTABLISH AND MAINTAIN A DATABASE OF THE FINDINGS
- UHCL CONTACT: DR. GLEN HOUSTON



PLANNED TASKS

- ARTIFICIAL INTELLIGENCE:
 - COMPUTER GRAPHICS TESTBED TO SIMULATE AND TEST VISION SYSTEMS FOR SPACE APPLICATIONS - UHCL CONTACT: DR. TERRY FEAGIN
 - ROBOT PATH PLANNING - UHCL CONTACT: DR. TERRY FEAGIN
 - APPLICATION OF FUZZY SETS AND RELATED THEORY TO FAILURE DETECTION AND CONTROL IN SPACE SYSTEMS - UHCL CONTACT: DR. GLENN HOUSTON
- INFORMATION MANAGEMENT
 - COMMERCIAL PAYLOADS DATABASE - UHCL CONTACT: DR. PETER BISHOP
- MATHEMATICAL AND STATISTICAL ANALYSIS
 - SPACE STATION MOMENTUM MANAGEMENT AND ATTITUDE CONTROL - UHCL CONTACT: DR. GLEN HOUSTON
- COMPUTER SYSTEMS AND SOFTWARE ENGINEERING
 - SYMBOLIC INFORMATION MANAGEMENT IN Ada TESTING
 - AUTOMATED SOFTWARE VERIFICATION TOOLS
 - FURTHER ANALYSIS OF EXPERT SYSTEMS IN Ada
 - SECURITY ISSUES FOR SPACEBORNE COMPUTER NETWORKS
 - UHCL CONTACT: DR. CHARLES MCKAY



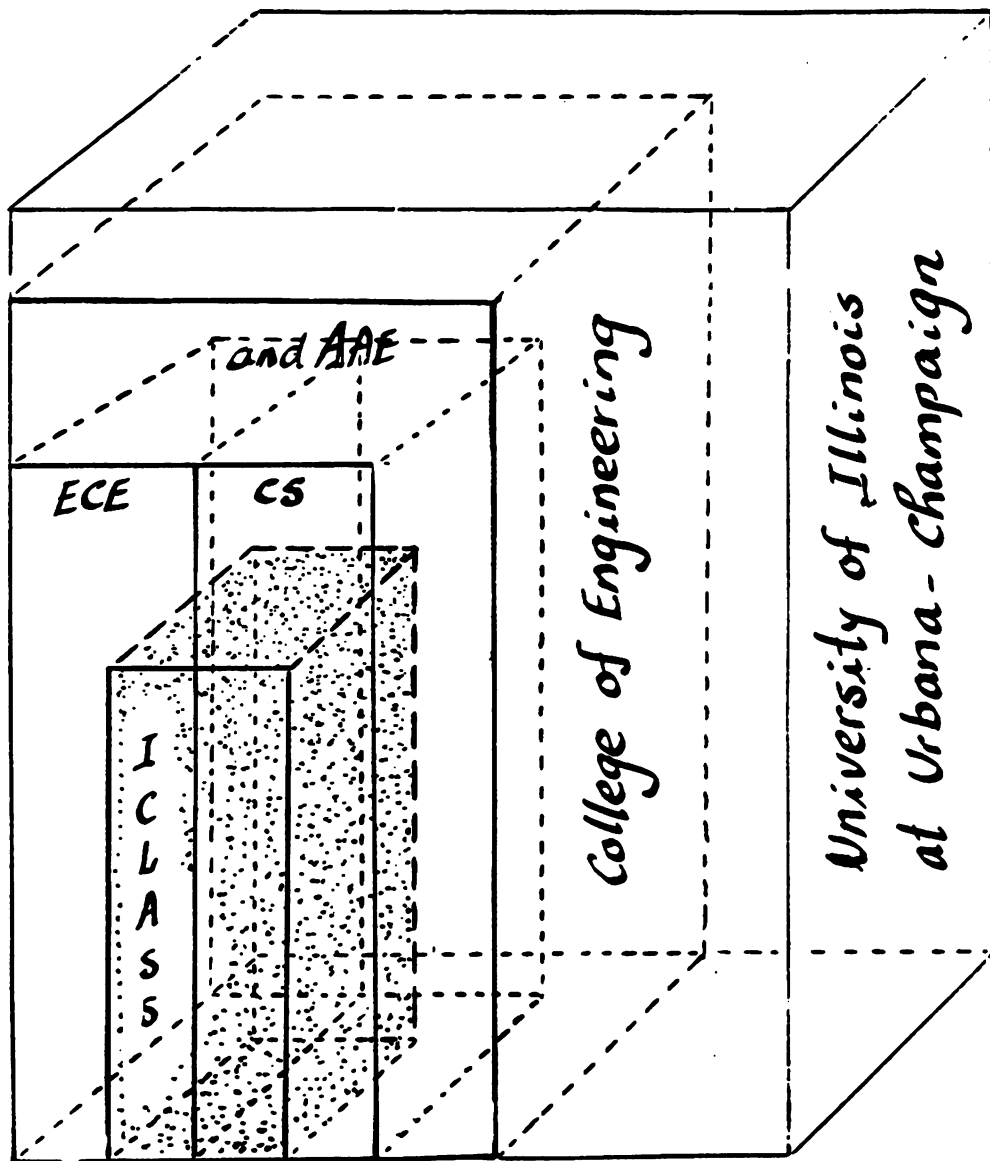
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SUMMARY AND DISCUSSION

- THE RICIS COOPERATIVE AGREEMENT HAS PROVEN TO BE AN EFFECTIVE METHOD OF ESTABLISHING RESEARCH ACTIVITY AT JSC
- THE NEED FOR RESEARCH IN COMPUTING AND INFORMATION SYSTEMS WILL REMAIN HIGH
- SOFTWARE LABOR ABSORBING EVER INCREASING PERCENTAGE OF PROJECT BUDGETS
- DRAMATICALLY INCREASING CAPABILITY OF COMPUTING HARDWARE
- ONE BIG QUESTION: WHAT WILL BE THE EFFECT OF MOVING FORWARD IN THE SHUTTLE AND STATION PROGRAMS
- AS SHUTTLE RETURNS TO OPERATIONAL STATUS AND STATION MOVES INTO DEVELOPMENT
 - PRESSURE SHIFTS TO GETTING JOB DONE
 - CONCERNS ABOUT USING LATEST TECHNOLOGY WANE
- TO ACHIEVE AND MAINTAIN EXCELLENCE IN COMPUTING TECHNOLOGY NASA'S COMMITMENT TO RESEARCH MUST REMAIN STRONG

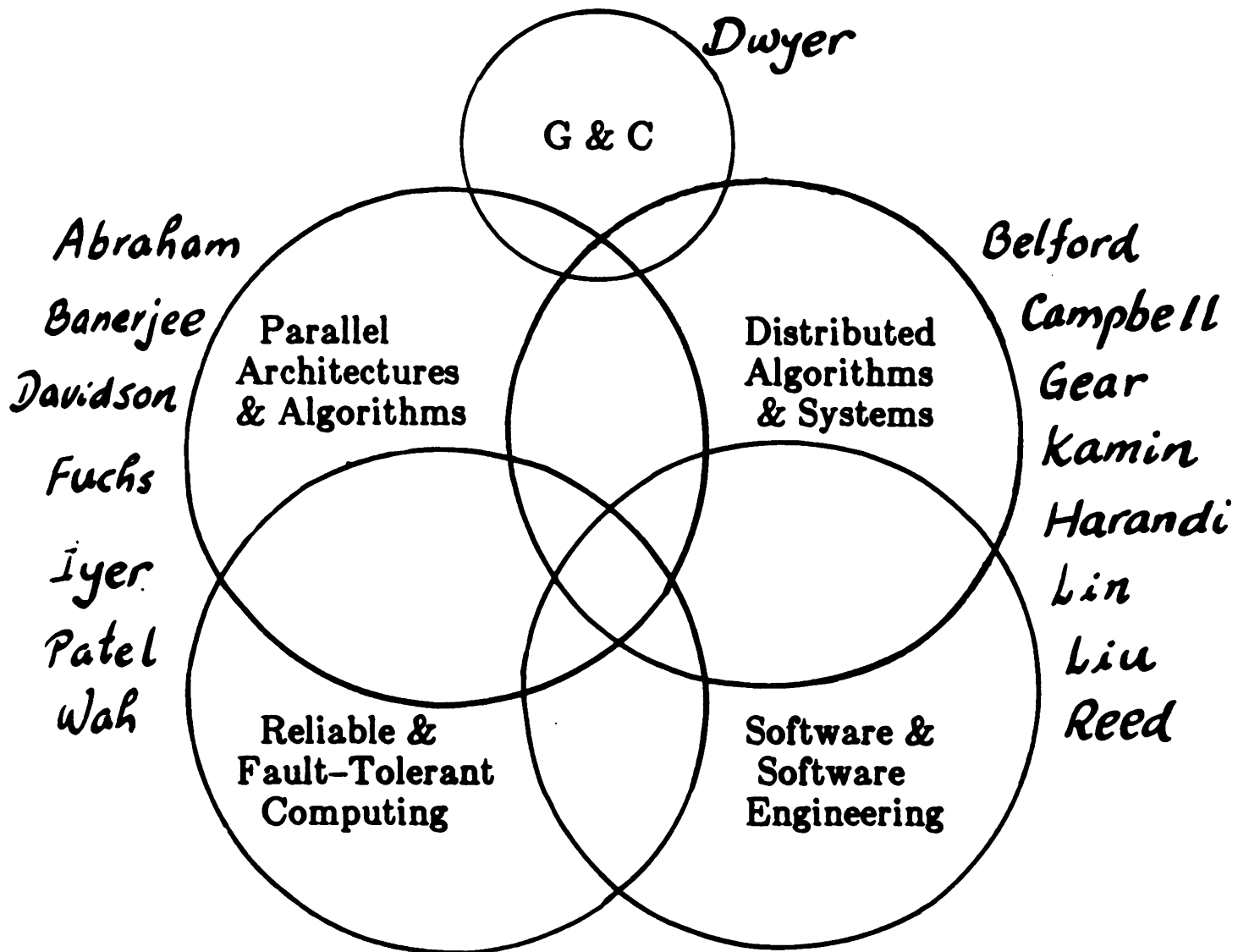
ICLASS

*Illinois Computing Laboratory of Aerospace
Systems and Software*



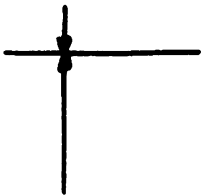
Objectives in education and research

ICLASS RESEARCH ACTIVITIES



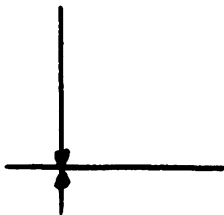
DISTRIBUTED SYSTEMS

*On
Dist.
DBMS*



- Reliable, Distributed Data Base Management Systems (*Belford*)
- Distributed File System for A Network of Workstations (*Iyer*)

*on
Dist.
OS*



- Adaptive Operating System for Message Passing Machines (*Reed*)
- Process Migration (*Liu*)
- Distributed, Macro Data Flow Architecture (*Liu*)

*on
Comm.
subnet*

- Integrated Communication Networks (*Reed*)

SOFTWARES AND SOFTWARE ENGINEERING

- A Type System for A Functional Programming Language (*Campbell*)
- Environments for Parallel Computation (*Gear*)
- A Program Development System (*Kamin*)
- Abstract, Executable Specification (*Kamin*)
- A Decentralized Debugging Service (*Lin*)
- Software Engineering Data Base and Project Management Support Systems (*Belford, Harandi, Liu*)

- Software design methods to support software reuse
- Reuse software libraries
 - ISADORA — numerical software
 - Clemma — part of SAGA
general library
- Interconnection language
 - Polylith — for interconnection
of different
modules on dist.
systems
- Open System architecture
- Object-base software engineering
database supporting version,
change monitoring and notification,

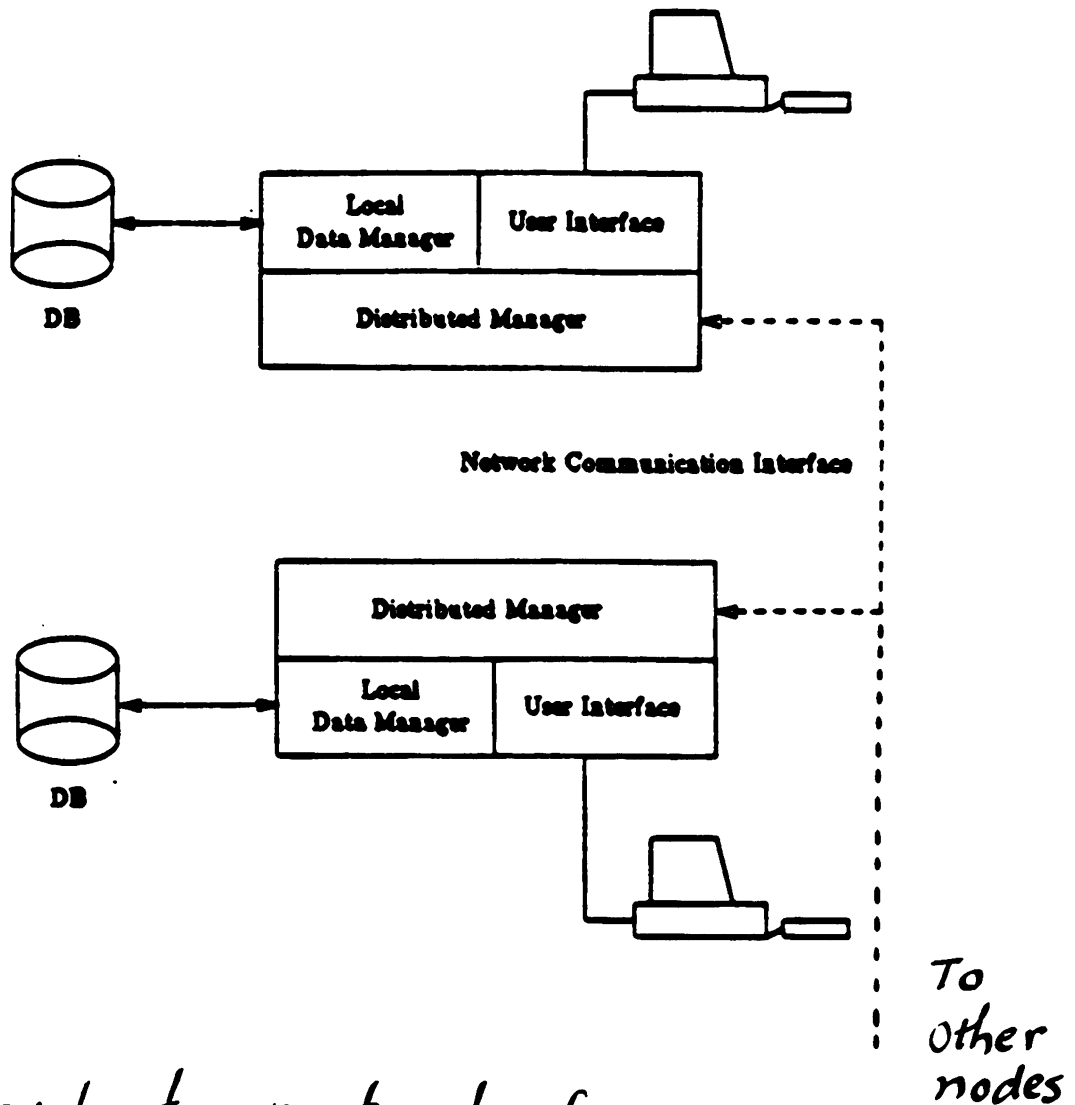
HIGH PERFORMANCE AND HIGHLY AVAILABLE DISTRIBUTED SYSTEMS

- **Distributed Task Assignments**
- **Load Balancing Algorithms**
- **Dynamic Control Structures**
- **Reconfiguration Schemes**
- **Process Migration**
- **Objected-Oriented, Data Flow Architecture**

**Three Implementation Projects
to build
DISTRIBUTED SYSTEMS**

- *DROLL*, A Distributed Testbed for DDBMS Algorithms and Protocols.
- *PICASSO*, A Adaptive Distributed Operating System
- *MENTAT*, A Object–Oriented, Macro Data Flow System

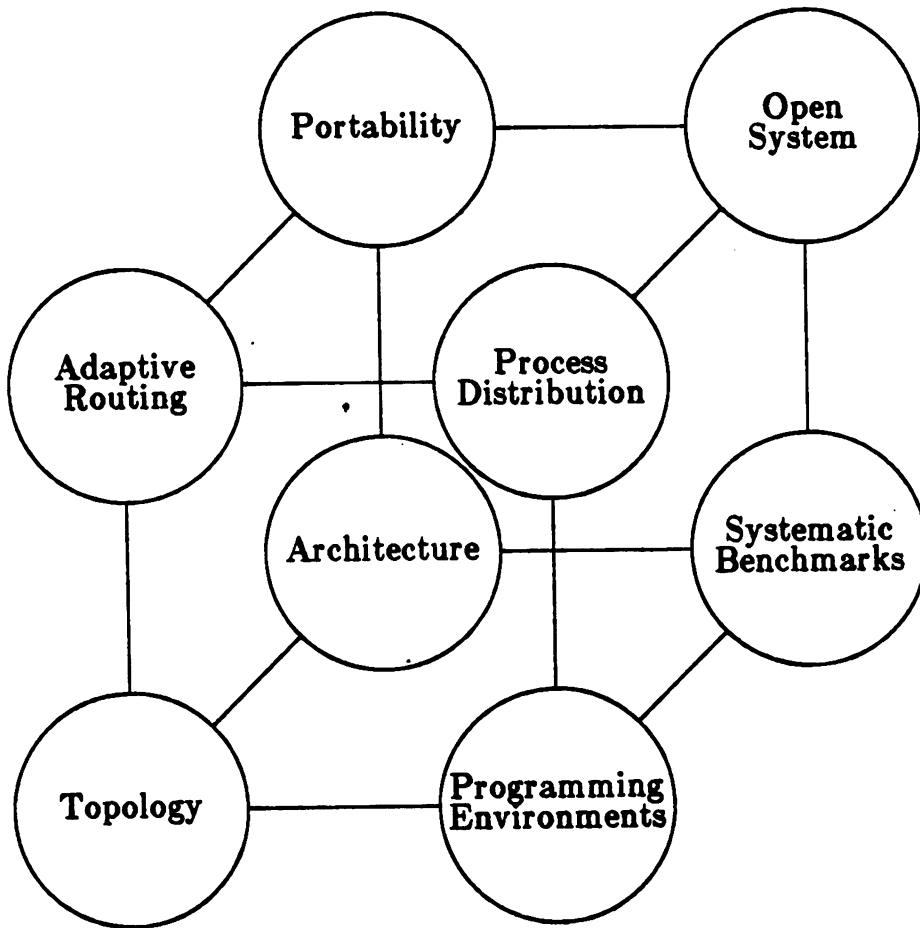
DTROLL, A Test Bed



To evaluate protocols for

- Concurrency control
- Failure detection and recovery

The Cornerstones of Picasso



Picasso Will Provide

- A frame-work for testing and evaluating message routing & load sharing methods
- An open, layered, and expandable basis for operating system design and experimentation
- A portable, efficient environment for parallel algorithm development

Only by advancing the state of the art in programming environments for message passing computers can we realize the promise of effective large-scale parallelism.

Using adaptive routing, dynamic load sharing and a consistent system representation, Picasso will engender solutions which harness parallelism while maintaining clarity and reliability.

MENTAT

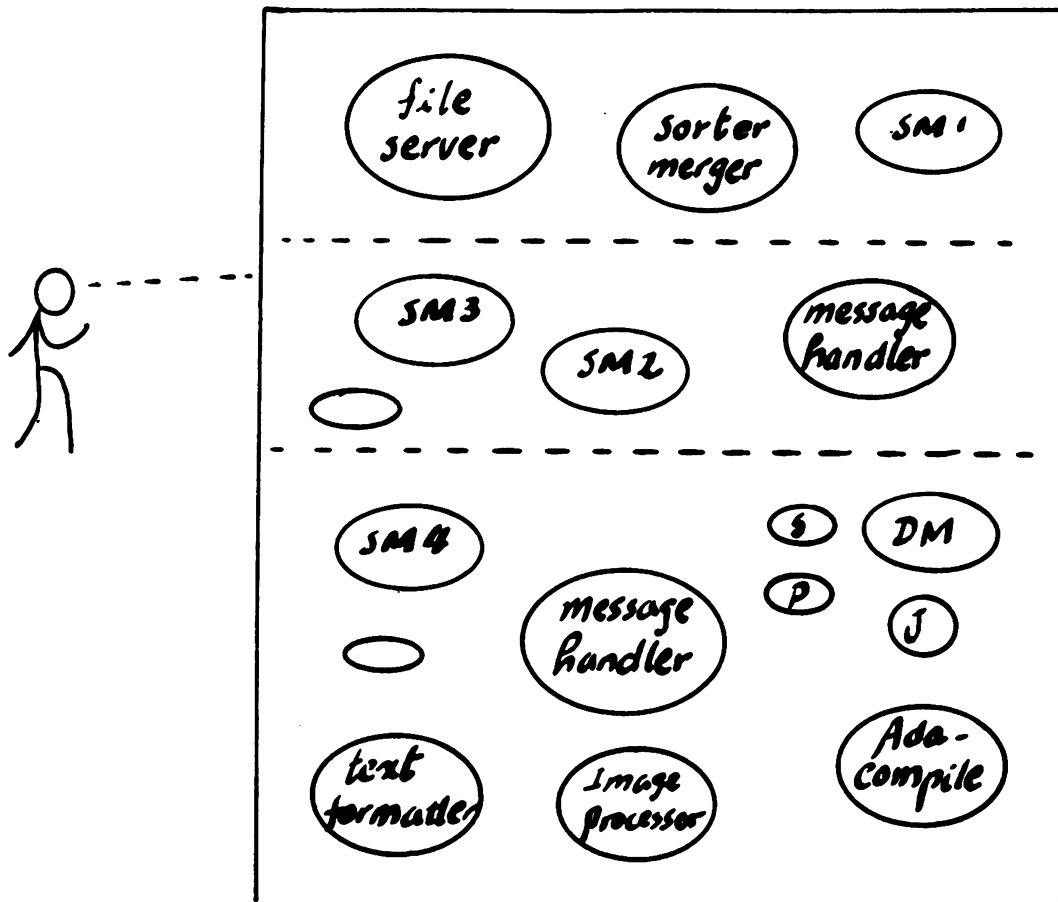
An Objected-Oriented, Data Flow Machine

OBJECTIVES

- To provide an environment conducive to distributed software development and effectively supports software reuse
- To develop a high performance distributed system in which the degree of parallelism is maximized

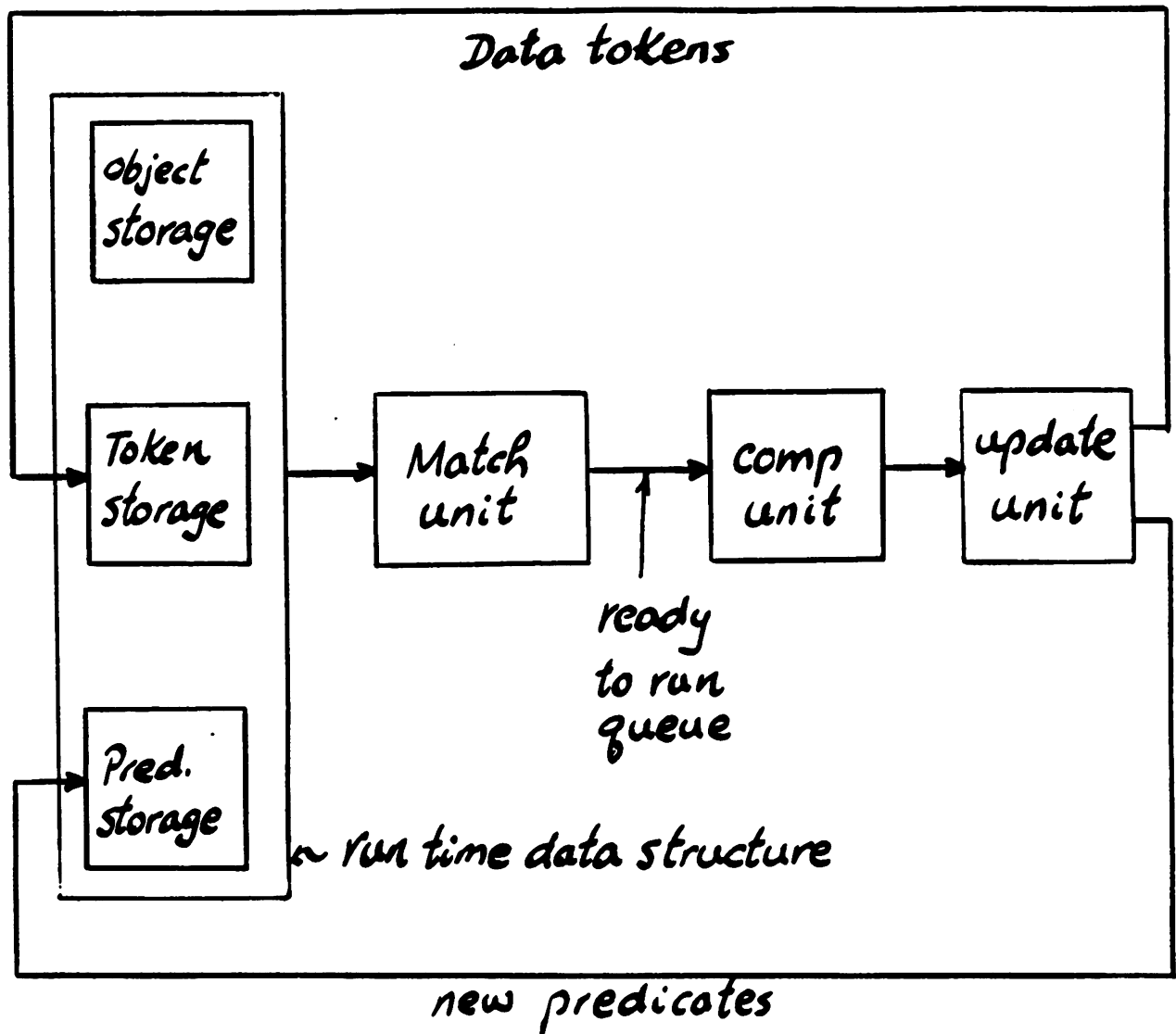


Distributed Macro Dataflow Machine



- Components of MENTAT :
 - Actor - Objects
 - Token or messages
- Programming Languages :
C++ and Ada

A Macro Data Flow Machine



Run Time Support in MENTAT

Summary of ICLASS Activities

Systems and Software Engineering

An adaptive DOS	Environments for Pa. Pro.
A macro data flow architecture	A type system for a FP
Process migration	Abstract, executable specification
	A program development system
	A decentralized debugging service
Distributed file systems for networks of workstations	
Reliable, distributed DBMS	Software engineering data base and project management support systems

OVERVIEW OF ICLASS RESEARCH: RELIABLE AND PARALLEL COMPUTING

R. Iyer

**Computer System Group
Coordinated Science Laboratory
University of Illinois at Urbana-Champaign**

ICLASS ACTIVITIES IN RELIABLE AND PARALLEL COMPUTING

- **6 Faculty, 10 students**
- **Research Areas**
 - Reliable Computing
 - Parallel Processing
- **Interaction with NASA Centers**
 - Student/Faculty visits to NASA facilities
 - Joint Research with NASA-Ames, JPL
 - Interactions with NASA Langley
- **Other Activities**

RELIABLE AND FAULT TOLERANT COMPUTING

● Automatic Recognition of Failure Symptoms

- ☐ Real time prediction of major system problems based on low-level error/recovery symptoms
- ☐ Prediction based on learning from observed behavior

● Structure Based Error Detection

- ☐ Detection of major software problems
- ☐ Detection of hardware failures affecting software integrity

● Algorithm-Based Fault Tolerance

- ☐ Takes advantage of unique features of the algorithm
- ☐ Cost effective for specific application e.g. signal processing, Matrix Manipulations

RELIABLE AND FAULT TOLERANT COMPUTING

● Fault Latency: Experimental Study

- ☐ Simulation based study using real workload data
- ☐ Accurate evaluation of fault latency distributions
- ☐ Latency distributions valuable for accurate reliability prediction and estimation of multiple failures

PARALLEL PROCESSING - APPLICATIONS

● Image Processing

- ☐ Low level operations e.g. convolution, filtering
- ☐ High level operations e.g., connected components
- ☐ Unique feature is handling both in real time

● Design Automation

- ☐ Standard Cell Placement
- ☐ Wire Routing
- ☐ Unique feature is use of hypercube to give large speedup instead of special purpose CAD accelerators

● AI Algorithms and Software

- ☐ Development of heuristic rules to guide parallel run-time search for LISP and PROLOG programs
- ☐ Investigation of architectures to support parallel search techniques

PARALLEL PROCESSING

● Architecture

- ☐ Reduction in communication overhead
- ☐ Efficient use of local memory
- ☐ Study of memory referencing characteristics for individual locations

● Measurement-based Evaluation

- ☐ Concurrency Measurements
 - Hardware Monitoring
 - Software Instrumentation
- ☐ Relating concurrent program behavior to system resource usage

AUTOMATIC RECOGNITION OF FAILURE SYMPTOMS

R. K. Iyer, L. T. Young and V. Sridhar

**Computer Systems Group
Coordinated Science Laboratory
University of Illinois at Urbana-Champaign**



OBJECTIVES

- Recognize onset of persistent system problems based on observed relationships between low level recoverable errors
- Differentiate between transients and intermittents
- Quantify the strength of the captured relationships

BACKGROUND/MOTIVATION

- Early recognition of symptoms of persistent errors usually not possible
- Causes usually complex--may affect different parts of a system
- Detection commonly occurs as many isolated incidents
- Incorrect diagnosis leads to improper recovery management —> affects system integrity
- To be effective, the system must examine seemingly unrelated error events for possible relationships



SYMPTOM RECOGNITION

1. Clustering of identical errors
2. Identification of sudden rise in failure rate—**GROUPING**
3. Identification of **EVENTS**—"Similar" groups
4. Identification of **SUPER EVENTS**—"related" events
5. Quantification of the strength of inter-record relationships

VALIDATION OF FAILURE SYMPTOMS

● Probabilistic Validation

$$P(A_1)*P(A_2)*...*P(A_n) < P(A_1, A_2, \dots, A_n)$$

$$\text{Strength (S)} = \frac{P(A_1)*P(A_2)*...*P(A_n)}{P(A_1, A_2, \dots, A_n)}$$

● Group Level Validation

- ☐ Complete Analysis
- ☐ Subset-Based Analysis

● Event-Level Validation

- ☐ Inter-Group Analysis

● Super Events

- ☐ Inter-Event Analysis

SUMMARY

1. Demonstrated a technique for fault isolation
2. Allows resolution between independent and dependent causes, transients and intermittents
3. Estimates strength of relationship among dependent failures (useful in prediction)
4. Can evaluate effectiveness of new diagnostic techniques

FUTURE RESEARCH

- Current results show that real-time diagnosis is feasible
- Develop strategies for on-line diagnosis and reconfiguration for complex multi-computer systems
- Perform hardware and software error injection experiments on network of workstations
- Extension to symbolic architectures
- Investigate feasibility of on-line software "repair" routines

What is CASIS?

- CASIS is Stanford's Center for Aeronautics and Space Information Sciences
- CASIS was founded in March, 1983 with the support of a block grant from NASA's Office of Aeronautics and Space Technology
- CASIS was founded as a multi-disciplinary, cross-departmental research structure which would provide faculty and students with an opportunity to participate in a variety of space-related projects relating to activities of the U.S. civil space program
- CASIS includes 13 Stanford faculty, 9 professional research staff, 31 graduate students, and 6 undergraduates
- The CASIS administrative offices, the central computer facilities, and the CASIS Experiment Laboratory are located in Durand Building. Participating projects are located in various CSD and EE buildings on campus

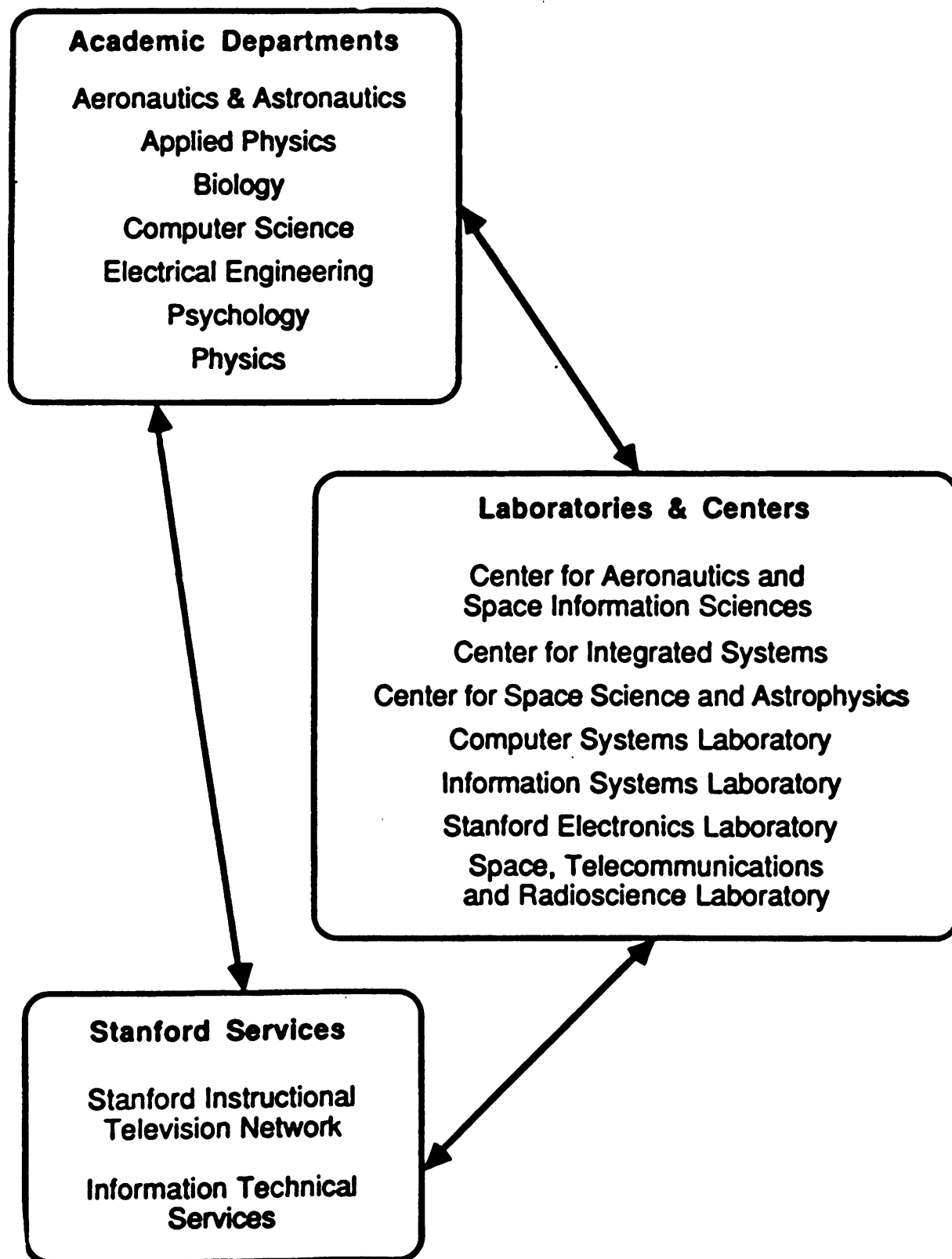
CASIS Governance

- CASIS is governed under a charter approved by the Stanford School of Engineering and the Provost of the University
- The overall direction of the center is provided by the Director, Prof. Peter M. Banks.
- Day to day operations are under the direction of the Associate Director, Dr. Michael J. Wiskerchen.
- Policy decisions for CASIS are reviewed by the CASIS project investigators
- Progress of research projects and associated budgets are monitored by the Director in collaboration with individual research project leaders
- The practical responsibility for research work lies in the hands of the research leaders
- The Director reports to the Associate Dean for Research in the School of Engineering

CASIS

- Center for Aeronautics and Space Information Sciences
- NASA OAST HQ block grant in information sciences
- Advanced information sciences technology research
- Core technology for "TELESCIENCE" applications research
- Advanced technology for Shuttle and Space Station applications

STANFORD RESOURCES



Center for Aeronautics and Space Information Sciences
CASIS

- **Concurrency Studies**
 - Researchers: M. Flynn, S. Owicki, S. Lunstrom - 5 students
 - Performance of Highly-Concurrent Systems
 - Models of Parallel Programs
 - Highly Reliable Concurrent Programs
- **Network Graphics and User Interface Architecture**
 - Researchers: K. Lantz - 4 students
 - Virtual Graphics Terminal Service
 - User interface architecture: Terminal management
 - Command specification and response handling -
 - application specific interaction - multi-application management.

CURRENT CASIS RESEARCH

- **Studies in Computer Concurrency-- Prof. M. J. Flynn**
- **High Speed Local Area Networks-- Prof. F. A. Tobagi**
- **High Performance VLSI Signal Processors--
Prof. A.M. Peterson**
- **Parallel Computing Arrays for Signal Processing--
Prof. T. Kailath**
- **Satellite Communications for Space Science Data
Systems-- Prof. B.B. Lusignan**
- **Network Graphics and User Interface Architecture--
Prof. K.A. Lantz**
- **Large Volume Database Management--
Prof. G. Wiederhold**
- **Rapid Image Retrieval for Remote Sensing Data--
Prof. P.M. Banks**
- **Advanced Video Systems and Robotic Vision Systems
for Scientific Analysis-- Dr. M.J. Wiskerchen**
- **Highly Concurrent Systems-- Prof. S.F. Lunstrom**
- **Reliable Concurrent Programs-- Prof. S.S. Owicki**

Center for Aeronautics and Space Information Sciences
CASIS

- High Speed Local Area Networks
 - Researchers: F. Tobagi, M. Mahric - 4 students
 - Topological Design of Fiber Optics LANs
 - Study of Media Access Protocols
 - Design and Implementation of the Network Interface
 - EXPRESSNET implementation
- Telecommunications Research
 - Researchers: B. Lusignan - 5 students
 - Efficiency modeling of satellite digital transmission
 - Study of new modulation techniques
 - C-MOS integrated circuit design for radio-channel equipment
 - Efficiency models for fiber-optic digital networks
 - Optimization modeling for digital communications components
 - Digital Telecommunications switch development

**Center for Aeronautics and Space Information Sciences
CASIS**

- **Parallel Computing Arrays for Signal Processing**
 - Researchers: T. Kailath - 2 students
 - Parallel Algorithms and Architectures for Kalman Filtering
 - Schur vs. Levinson Algorithms for Stationary and Nonstationary Processes in Data Communications
- **Advanced Concepts for Remote Space Science Operations**
 - Researchers: P. Banks, P. Williamson, R. Clauer, M. Wiskerchen - 6 students
 - Telescience Research for Shuttle and Space Station Systems
 - Distributed Computer Graphics Networks

Center for Aeronautics and Space Information Sciences
CASIS

- High Performance Signal Processors
 - Researchers: A. Peterson, I Linscott - 3 students
 - PROLOG language as a processor description tool and VLSI CAD systems
 - High performance architectures with relational processing
 - Real time parallel processing - Scheduling Theory approach
 - Optimization of pipelined processor using linear programming
- DataBase Management Architectures
 - Researchers: G. Wiederhold, P. Rathman, H. Waquar - 4 students
 - Database design and operation methods and algorithms
 - Optical storage technology

New CASIS Research Topics

- 1. Color Stereoscopic Video Systems-- Prof. P.M. Banks, EE**
- 2. Speech Recognition and Analysis-- Prof. R. M. Gray, EE**
- 3. VLSI Tactile Sensors-- Dr. P.W. Barth, CIS**
- 4. ADA Development for Space Systems--
Prof. D. C. Luckham, EE**
- 5. Distributed Network Architectures for A.I. Work Stations
--Dr. T.C. Rindfleish, CSD**
- 6. Human Factors for Space Experiment Operations-- Dr. M.
J. Wiskerchen, EE**

TELESCIENCE

Perform "Science in Space" like in a ground-based laboratory throughout the entire life cycle; from instrument development through operations to the reduction of data to new knowledge and its publication

Definition:

The direct, iterative and distributed interaction of users with their instruments, data bases, specimens and data handling facilities, especially where remote operations are essential

The distributed interaction is meant to include ALL members of a user team, in space and on the ground, and may involve either manned or unmanned operations. It is the general desire of the user community to conduct their operations from their home institution by on-line computer networking.

TELESCIENCE

Can be divided into three portions, centered on pre-flight, flight, and post-flight:

1. Teledesign

The ability to send drawings, documents and specifications, to perform interactive design with remote facilities, and to conduct interface and other tests of instruments by remote computer access.

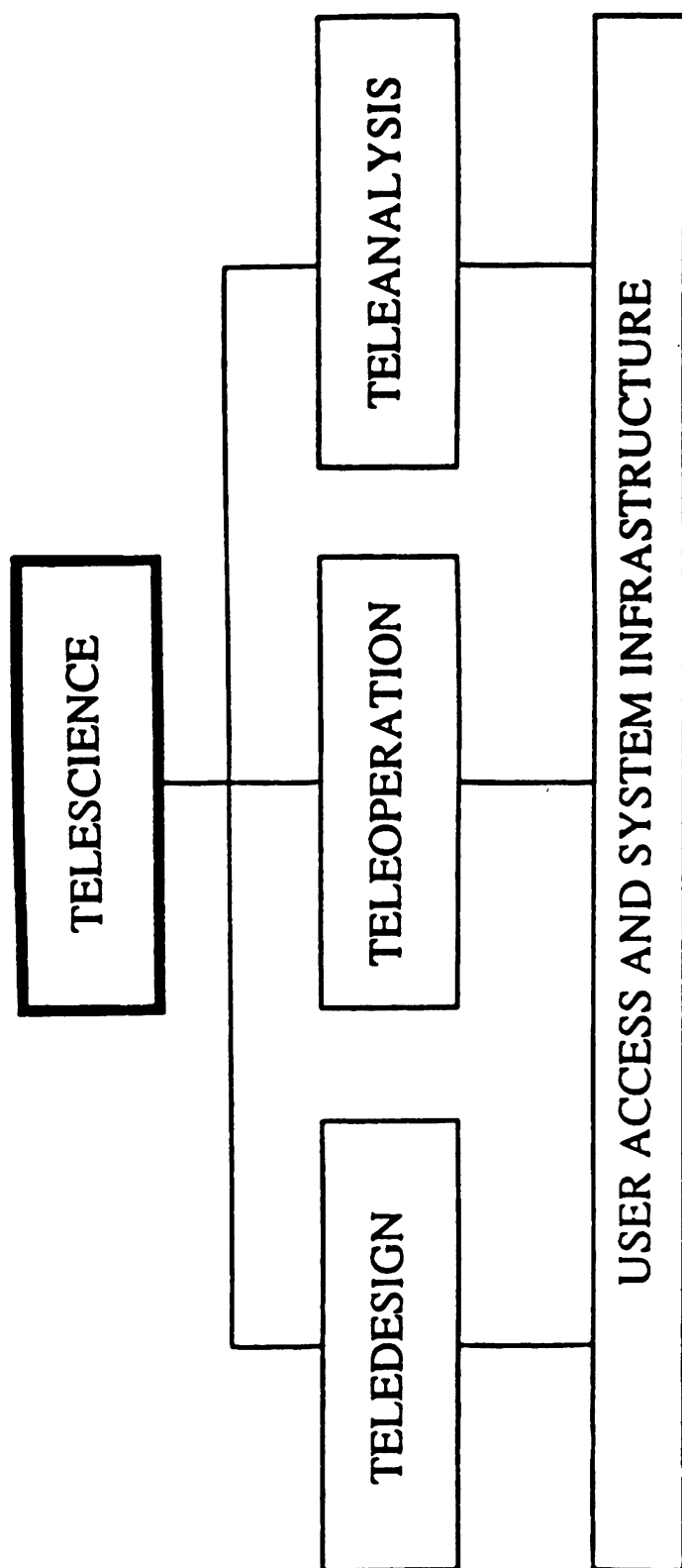
2. Teleoperations

The ability to conduct remote operations by making rapid adjustments to instrumental parameters and experiment procedures in order to obtain optimum performance.

3. Teleanalysis

The ability to access and merge data from distant sources and to perform analyses and studies on computers that may be located at other institutions.

TELESCIENCE CONCEPT



SUNSTAR PROGRAM

M. J. Wiskerchen — STARLAB/SEL

VALUE OF TELESCIENCE

- **ENHANCES PRODUCTIVITY OF REMOTE OPERATIONS**
 - Gives better use of local and remote human resources
 - Reduces mistakes
 - Provides a capability to quickly investigate new or unexpected phenomena
- **SHARPENS FOCUS OF SPACE RESEARCH OPERATIONS**
- **PROVIDES COORDINATION OF EXPENSIVE RESOURCES**
- **PROVIDES DESIGN GOALS FOR SYSTEM PLANNERS**
- **GIVES FOCUS TO NEW TECHNICAL NEEDS TO SUPPORT SCIENTIFIC RESEARCH OPERATIONS**

Technical Challenges for Telescience

1. Restricted bandwidth in telecommunication channels

- **Need for information compression**
- **Dynamic channel selection based on usage models**
- **New modes of communication (e.g., electro-optics)**
- **Use of object coded definitions for graphics**

2. Finite signal propagation time

- **Look-ahead capabilities for experiments and operations**
- **Autonomous operations**
- **Advanced local simulation of remote system behavior**

3. Integrated information acquisition and dissemination

- **Digital data to include images, voice, computer**
- **Development of appropriate packet techniques**
- **Main link vs. local and remote distribution, capture and processing**

4. Spatial diversity of user centers for single experiment sites

- **Control and command models**
- **Sharing of current information**
- **Segregation of returning information to local addressees**
- **Standard interfaces and access protocols**

5. Human interactions

- **Integration of voice, image and computer information for experiment control**
- **Optimization of cognition for "adaptive" science**
- **Balance between automatic sequences and timely direct control**
- **The value of local simulated and time-delayed experiment images**

6. Tool development

- **Voice coding and synthesis**
- **Voice recognition and computer interaction**
- **Simulation 3-d graphics**
- **Stereoscopic video**
- **High definition video**
- **Knowledge-based operations planning**
- **A.I. for remote instruments and support equipment**
- **A.I. for local site system configuration and operation**
- **Hardware support for network graphics**
- **High-bandwidth local area network for mixed mode data**
- **Query language database management**

7. Cost issues

- **System costs must match user needs**

8. Reliability

- **Needs will vary according to the telecommunications channels used and the type of project**

TELESCIENCE

NEW ENGINEERING PHILOSOPHY

A NEW, UNIFYING CONCEPT BASED ON THE NEED TO IMPROVE THE WAY REMOTE RESEARCH OPERATIONS ARE CONDUCTED IN SPACE AND IN A TERRESTRIAL ENVIRONMENT

WILL PROVIDE A DESIGN GOAL FOR SPACE STATION TECHNICAL DEVELOPMENTS

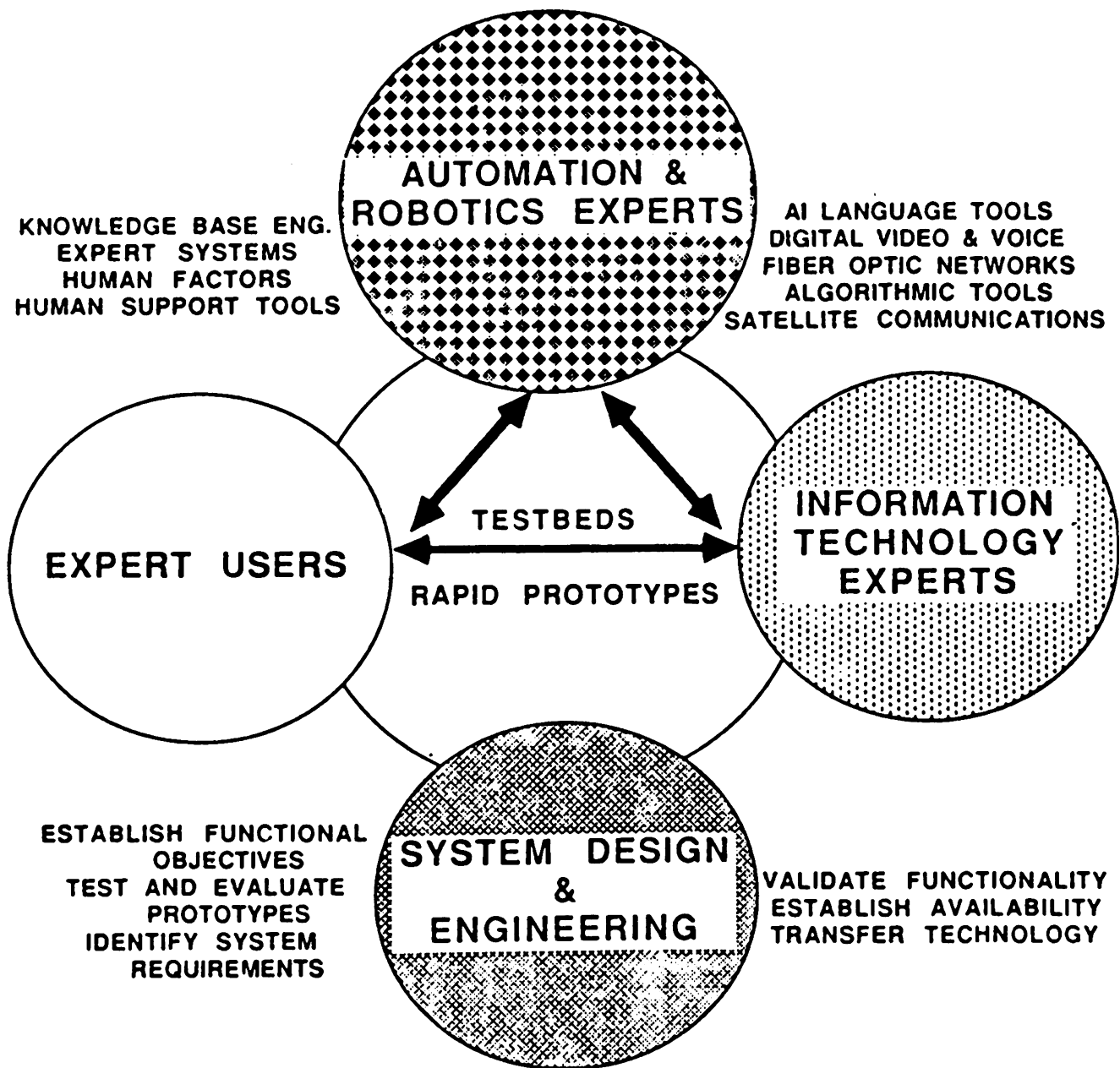
HAS STRONG TIES TO AUTOMATION, ROBOTICS, EXPERT SYSTEMS, COMPUTER VISION, AND OTHER TOPICS RELATED TO KNOWLEDGE-BASED ENGINEERING

IS AT THE FOREFRONT OF NEW APPLICATIONS INVOLVING HUMAN FACTORS ENGINEERING

PROVIDES A MECHANISM FOR UNIVERSITIES, INDUSTRY AND GOVERNMENT TO WORK TOGETHER ON RESEARCH AND TECHNOLOGY PROGRAMS

PROMOTES THE USE OF RAPID PROTOTYPING CONCEPTS AND TESTBEDS TO DEVELOP FUNCTIONAL SYSTEM DESIGNS

PROVIDES NEW OPPORTUNITIES FOR UNIVERSITY-BASED RESEARCH AND PILOTS



UNIVERSITY CONSORTIUM FOR SPACE STATION TELESCIENCE RESEARCH

PURPOSE:

PROVIDE A MEANS FOR THE UNIVERSITY SPACE SCIENCE COMMUNITY TO INVESTIGATE, DEVELOP AND VALIDATE FUNCTIONAL REQUIREMENTS FOR THE DESIGN OF THE SPACE STATION

APPROACH:

DO EXPERIMENTS WITH USERS ON PROTOTYPES OR TEST-BEDS AND EXTRACT DATA FOR EVALUATION OR TRADE-OFF ANALYSIS

REQUIRES A TEAM INCLUDING EXPERIMENT EXPERTS, SYSTEM ENGINEERS, USER ANALYSTS AND PROTOTYPERS

PROCESS:

FRAMEWORK OF THE PROCESS IS AS FOLLOWS:

- OPERATIONS CONCEPT**
- USER ANALYSIS**
- TASK ANALYSIS**
- MAN - MACHINE INTERFACE ANALYSIS**
- VALIDATION**

THE PROCESS IS NOT LINEAR BUT ITERATIVE AND RECURSIVE AND MUST BE SUPPORTED BY PROTOTYPES WHICH EVOLVE DURING THE PROCESS

SUNSTAR PROGRAM

M. J. Wiskerchen — STARLAB/SEL

- **RESEARCH IN PAYLOAD DESIGN, INTEGRATION AND OPERATIONS**
 - MSFC, GSFC, JSC, KSC, ARC, LeRC cooperative agreements
 - Stanford implements distributed network communications
 - Use Shuttle payloads as testbed for "TELESCIENCE" research

COOPERATIVE AGREEMENT RESEARCH

GODDARD SPACE FLIGHT CENTER

- Remote space science operations facility
- Integrated voice, video, computer work station
- CAD/CAE/CAM work stations
- Human factors research for operations and control systems
- Fiber optics local area networks
- Optical disk mass storage systems
- Parallel processor architectures
- Satellite network architectures
- Expert systems for operations centers
- Expert systems for communications control

MARSHALL SPACE FLIGHT CENTER

- Expert systems for payload timelines
- Local area network architectures
- Payload Operations Control Center studies
- CAD/CAE workstations
- Distributed engineering databases for payloads
- AI workstations

JOHNSON SPACE CENTER

- Fiber optics local area networks
- High performance work stations
- ADA software architectures
- Expert systems for operations and control
- High definition and digital video
- Optical storage systems and databases
- Satellite communications architectures
- Digital speech recognition and synthesis
- Speech and video compression

AMES RESEARCH CENTER

- Robotic vision systems
- Human factors research
- Parallel processor architectures for AI
- Speech recognition and synthesis
- Large computational architectures
- Computational algorithm development

COOPERATIVE AGREEMENT RESEARCH

LEWIS RESEARCH CENTER

Advanced Communications Technology Satellite -- system
architecture study

Expert systems for space station power system control & operations

KENNEDY SPACE CENTER

Remote testing and integration research
Expert systems for integration operations
Fiber optic local area networks



APPLICATIONS OF CASIS TECHNOLOGY

STANFORD/NASA CENTER COOPERATIVE AGREEMENTS

1. GSFC

ADVANCED COMMUNICATIONS DESIGNS
HUMAN FACTORS STUDIES FOR CONTROL CENTERS
MULTIMEDIA WORKSTATIONS
PARALLEL COMPUTING ARCHITECTURES
CAD & CAE GRAPHICS SYSTEMS
EXPERT SYSTEMS APPLICATIONS TO CONTROL CENTERS
REMOTE SCIENCE OPERATIONS CENTERS

2. KSC

AUTOMATION AND ROBOTICS APPLICATIONS TO ORBITER
PROCESSING, LAUNCH OPERATIONS, AND PAYLOAD
INTEGRATION AND PROCESSING

3. JSC

MULTIMEDIA OPERATIONS WORKBENCH
FIBER OPTIC LOCAL AREA NETWORKS
EXPERT SYSTEM APPLICATIONS
ADVANCED MISSION CONTROL CENTER DESIGN
SPACE STATION TELESCEINCE TESTBED PROGRAM

4. MSFC

ADVANCED CONCEPTS IN PAYLOAD OPERATIONS CONTROL
CENTERS AND REMOTE SCIENCE OPERATIONS CENTERS
EXPERT SYSTEM APPLICATIONS TO PAYLOAD OPERATIONS

5. LeRC

DESIGN STUDIES FOR THE ACTS PROGRAM

SUNSTAR PROGRAM

M. J. Wiskerchen — STARLAB/SEL

- **AUTOMATION AND ROBOTICS**

- Timeline engineering using expert systems
- Vision systems in payload robotics
- Computer architectures for robotics
- AI languages
- Communication networks for robotics
- Robot systems for payload control
- Human factors research for man-machine interfacing
- Expert systems for payload integration

Space Systems Integration and Operations Research Applications (SIORA) Program



The SIORA Program is a joint Stanford/Lockheed initiative to accomplish near term applications of artificial intelligence, robotics, imaging systems, and other research products. Near term applications are to be achieved through rapid (6 to 24 months) development of prototype ground applications. This "rapid prototyping" will provide test beds or pilots for development and demonstration of technological approaches to integration and operation of space systems. Follow-on efforts will be undertaken to develop selected operational applications to benefit current or future space transportation systems and payloads.

BASIC THEMES OF THE SIORA PROGRAM

- **AUTOMATION AND ROBOTICS RESEARCH APPLIED TO SPACE SYSTEMS**
 - EMPHASIS ON INTEGRATION AND OPERATION
 - GROUND AND FLIGHT SYSTEMS SUPPORT
- **APPLICATIONS DRIVEN RESEARCH**
 - TASKS BASED ON OPERATIONAL NEED
 - WORK WITH LSOC AND KSC TO DEFINE INITIAL TASKS
- **A STANFORD/LOCKHEED TEAMING EFFORT**
 - UNIVERSITY/INDUSTRY RESEARCH PARTNERSHIP
 - POTENTIAL MODEL FOR GOAL ORIENTED RESEARCH PROJECTS
- **NEAR TERM RAPID PROTOTYPING: 6 TO 24 MONTH TIME FRAMES**
- **INITIAL SIORA TASKS WITH KSC; OTHER POTENTIAL TASK AREAS INCLUDE A & R RESEARCH APPLICATIONS FOR USAF-SCF, VAFB, AEROSPACE PLANE, DARPA, SDI, ETC.**



Institute For Computer Applications In Science and Engineering
ICASE

R. Voigt/LaRC

ICASE

Permanent Staff

R. G. Voigt - Director

M. Y. Hussaini - Chief Scientist

Visiting Staff -- 16-20 Ph.D.'s

Consultants

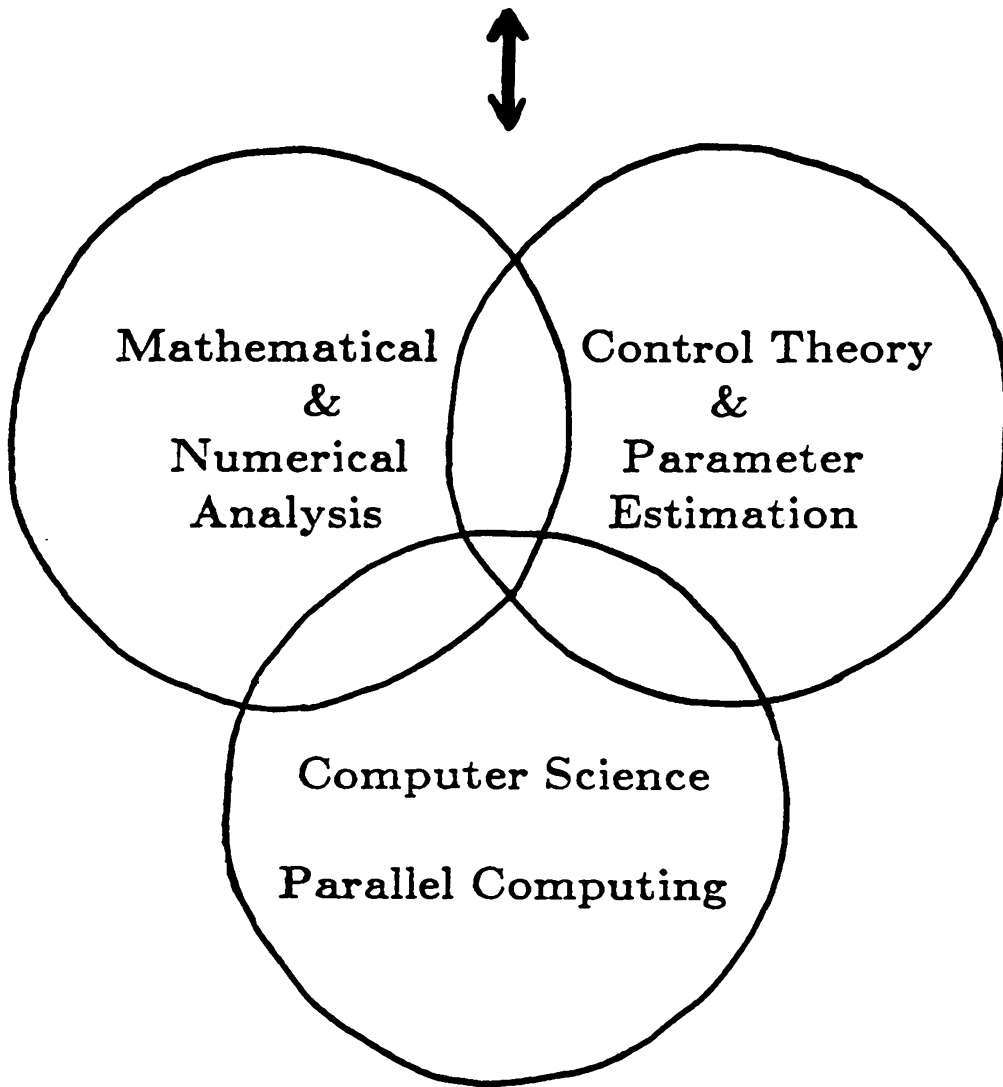
Summer Program

"Product"

75 Reports

2 - 4 Workshops/Conferences

LaRC Applications



VISIBILITY

13 Publications

**Second SIAM Conference on Parallel Processing &
Scientific Computing**

Active participation in variety of other meetings

4 Staff Scientists

10 Consultants

PARALLEL PROCESSING

Systems Issue

Alternative mathematical models

Numerical algorithms

Models of computation

Mapping problem

Dynamic load balancing

Communication & synchronization requirements

Programming environments

NUMERICAL ALGORITHMS

Modify order of computation to

- 1) Increase parallelism**
- 2) Decrease communication**
- 3) Decrease synchronization**

Numerical algorithms used for definiteness

SOR – 1)

Pivoting in Gaussian elimination – 1),2)

Time marching for PDE's – 1),2),3)

Multigrid – 1),2),3)

MODELS OF COMPUTATION

Predict performance of

algorithms on variety of architectures

different algorithms on same architecture

Permits study & optimization of parameters

Hardware

Software

**# processors
memory size
communication
arithmetic**

**problem size
process spawning
process switching
synchronization**

**Using iterative method for PDE demonstrated
weakness of Intel IPSC**

Packet size too large

Communication too slow

MAPPING PROBLEM

**Map subdivisions of problem onto processors to
minimize computation time**

OR

**Find subdivision that permits optimal mapping for
given architecture**

**Research focused on using graph representations of
algorithms & architectures**

**Efficient algorithms developed to find mappings for
specific graphs -- e.g. trees onto hypercubes**

**Technique developed for subdividing domain into subdomains
of equal work for adaptive mesh problems**

Demonstrated value of hexagonal subdivisions of domain

DYNAMIC LOAD BALANCING

All processors should have equal work

OR

**Inefficient use of processors
Longer execution times**

Solution: Rebalance

Problem: Not easy

Must account for cost of

**Detection
Computation of new distribution
Estimate of performance gain
Redistribution**

Work focused on developing and evaluating models of

Computation that can be analysed

COMMUNICATION & SYNCHRONIZATION

Goal: Eliminate **Consequence:** Algorithms fail

Reduction of frequency & amount

Model: SOR for PDE's

Advancing in time independently

Reducing communication cost of global convergence

Reducing frequency of global convergence

**Analysis of amount & impact for particular problem
mapping on variety of architectures**

Model: Adaptive mesh

Measurement of costs for running algorithms

PROGRAMMING ENVIRONMENTS

Force: Set of machine dependent macros that generate Fortran code

Constructs are machine independent
e.g. barrier synchronization

Facilitates programming & portability

Implemented on variety of machines

PISCES: Fortran based virtual machine concept

Provides view of machine appropriate for user's interests

Implemented on VAX, Apollos; to be on Flex/32

BLAZE: New parallel language designed to support scientific programming

Recognition of implicit parallelism

Implemented on VAX, Sun; next: RP3, Flex/32

ACTIVE AREAS OF RESEARCH AT RIACS

(Tying Computer Science to Computing in Science)

<u>ALGORITHMS</u>	<u>ACCESSIBILITY</u>	<u>LANGUAGES</u>
<ul style="list-style-type: none">• Computational Fluid Dynamics (CFD)• Computational Chemistry• Image Contour Extraction	<ul style="list-style-type: none">• Scientist's Workbench• Multimedia Mail and Conferencing• Network Protocols• Security	<ul style="list-style-type: none">• Graphical Shell• Concurrent C
<u>TESTBEDS</u>	<u>NEW ARCHITECTURES</u>	
<ul style="list-style-type: none">• Telescience Testbed• Center for Advanced Architectures (CAA)	<ul style="list-style-type: none">• Sparse Distributed Memory• Gas Lattice Automaton	

PROJECT: SPARSE DISTRIBUTED MEMORY

CHARACTERISTICS:

- Highly-parallel pattern computer
- Based on Kanerva's mathematical theory of human memory

PARTICIPANTS:

- Pentti Kanerva (RIACS), Project Manager
- Harrison Leong (RIACS)
- David Nagel (Ames)
- Michael Flynn (Stanford)

STATUS:

- Completed simulators
- Building digital prototype

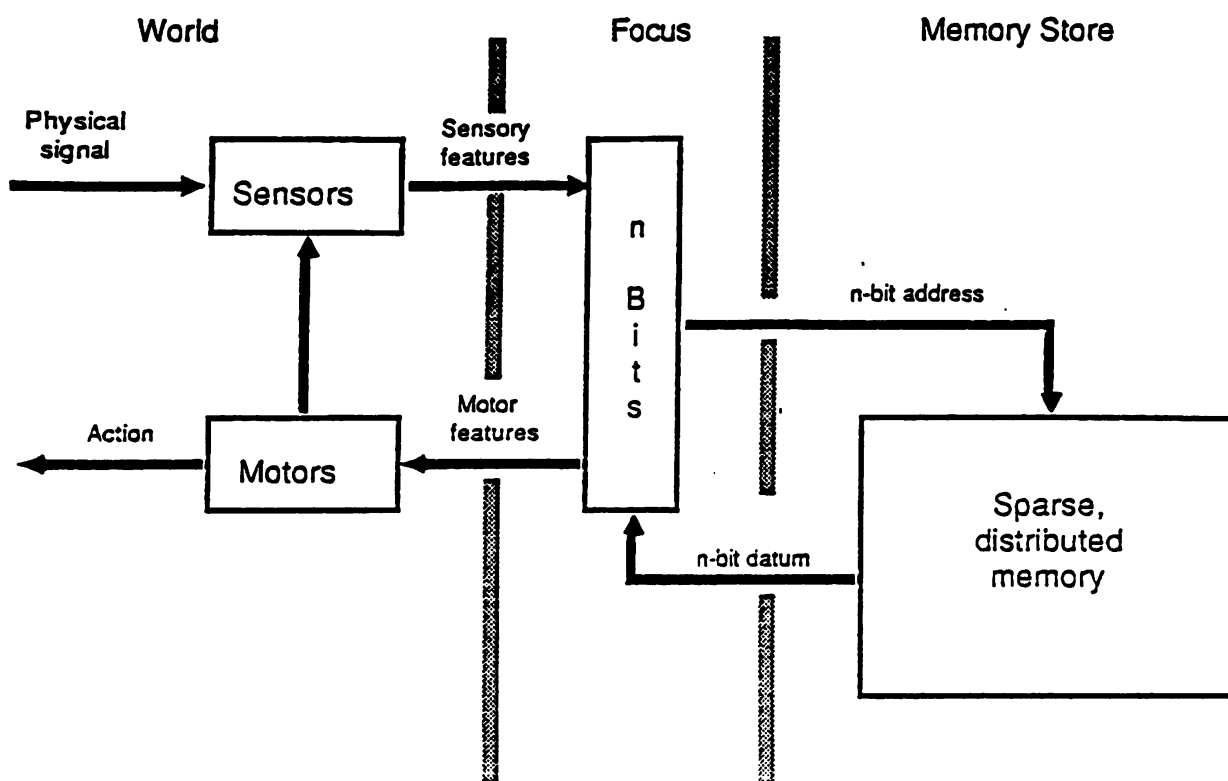


Figure 2. The coupling of the memory to the world. The memory stores a record of the system's past in a form presented to the focus by the system's sensors. The record can include features that control the system's motors. Selective action can be learned by explicit training and by trial and error.

another initial condition? (1=yes)

random (0) or perturbed initial condition(1)?

Which memory state to perturb around?

With what noise level? (0.0 to 1.0)

2 The initial condition is:

```
XX XXXX XX
X XXXX XX
XXXX XX XXXXXXXXXXXX
XXXXX XXXXXXXXXXXXXXX XXXX
XXXX XXXXXXXXXXXXXXX XX
XXXX XXXX XXXXXX XXXX
XXXX XXXX XXXXXXXXXXXX
XXXX XX XXXXXX XX
XXXX XXXXXXXX XXXX XX
X XX XXXX XXXXXXXX XX
XXXX XX XX
XXXXXXXXXX XX XXXXXX
XXXX XX XXXX XX XX
XX XX XXX XXXX
1-176 XXXX XXXXXXXX XXXXXXXX XX
XX
```

(initial condition)

type 1 'or' to continue

selected locations=11
XXXX

```
XXXX XXXX XXXXXXXXXXXX
XXXX XXXXX XXXXXXXXXXXX
XXXX XXXXX XXXX XX
XXXX XXXX XXXXXX XXXX
XXXX XXXX XXXXXXXXXXXX
XXXXXXXXXXXX XXXXXXXXXXXX
XXXXXXXXXXXX XXXX
XXXX XXXX XXXX XX
XXXX XXXX XXXX
XXXX XXXXXXX XXXX
XXXX XXXX XXXX
XX XXXX XXXX
XX XXXXX XXXXXXXX
```

Another iteration with this initial condition (1)?
1 selected locations=13

```
XXXX XXXX XXXXXXXXXXXX
XXXX XXXX XXXXXXXXXXXXXXX
XXXX XXXX XXXX XXXX
XXXX XXXX XXXX XXXX
XXXX XXXX XXXXXXXXXXXX
XXXXXXXXXXXX XXXXXXXXXXXX
XXXXXXXXXXXX XXXX
XXXX XXXX XXXX
XXXX XXXX XXXX
XXXX XXXX XXXX
XXXX XXXX XXXX
XXXX XXXX XXXX
XXXX XXXX XXXXXXXX
```

Another iteration with this initial condition (1)?
1 selected locations=14

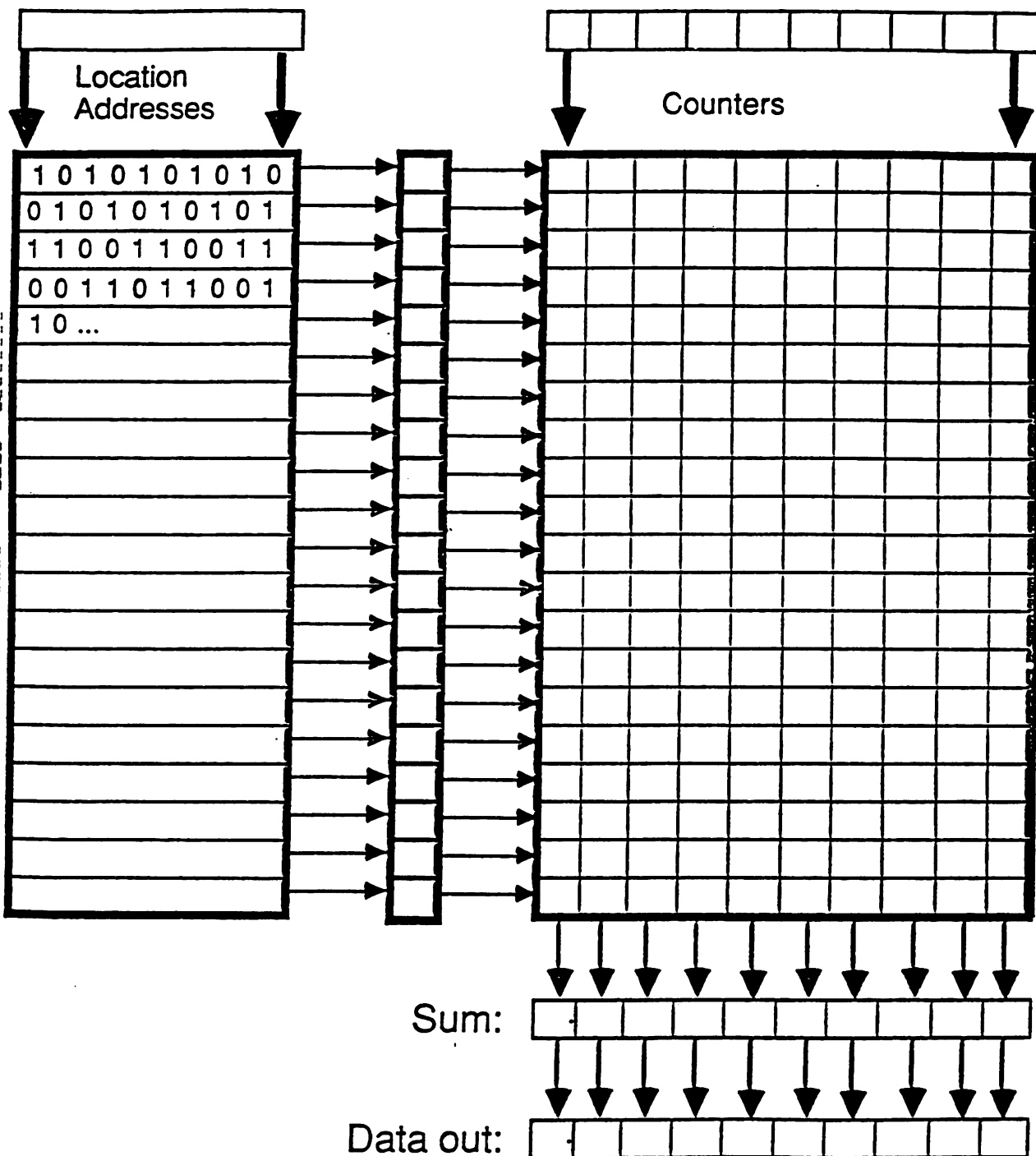
```
XXXX XXXX XXXXXXXXXXXX
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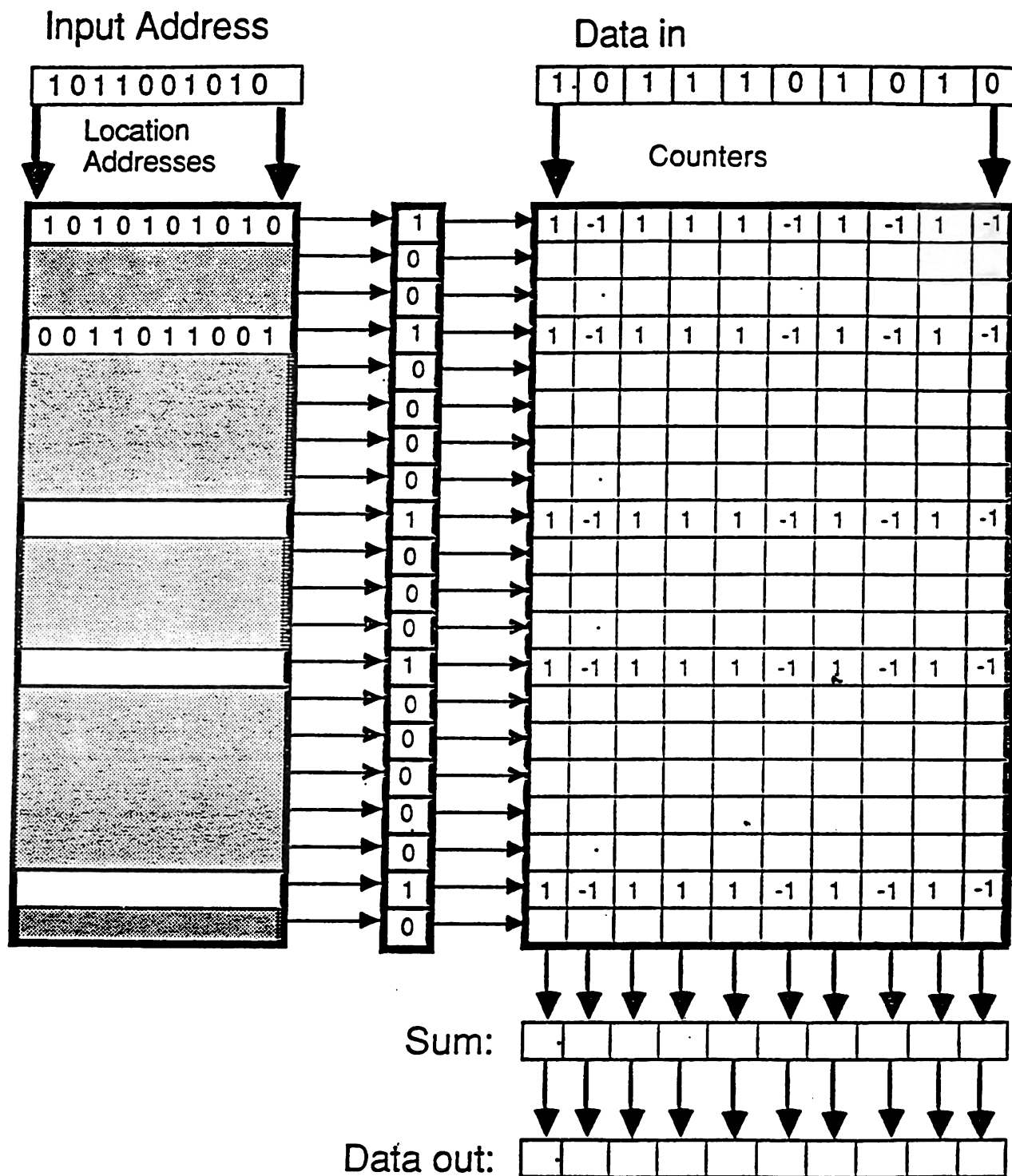
Input Address

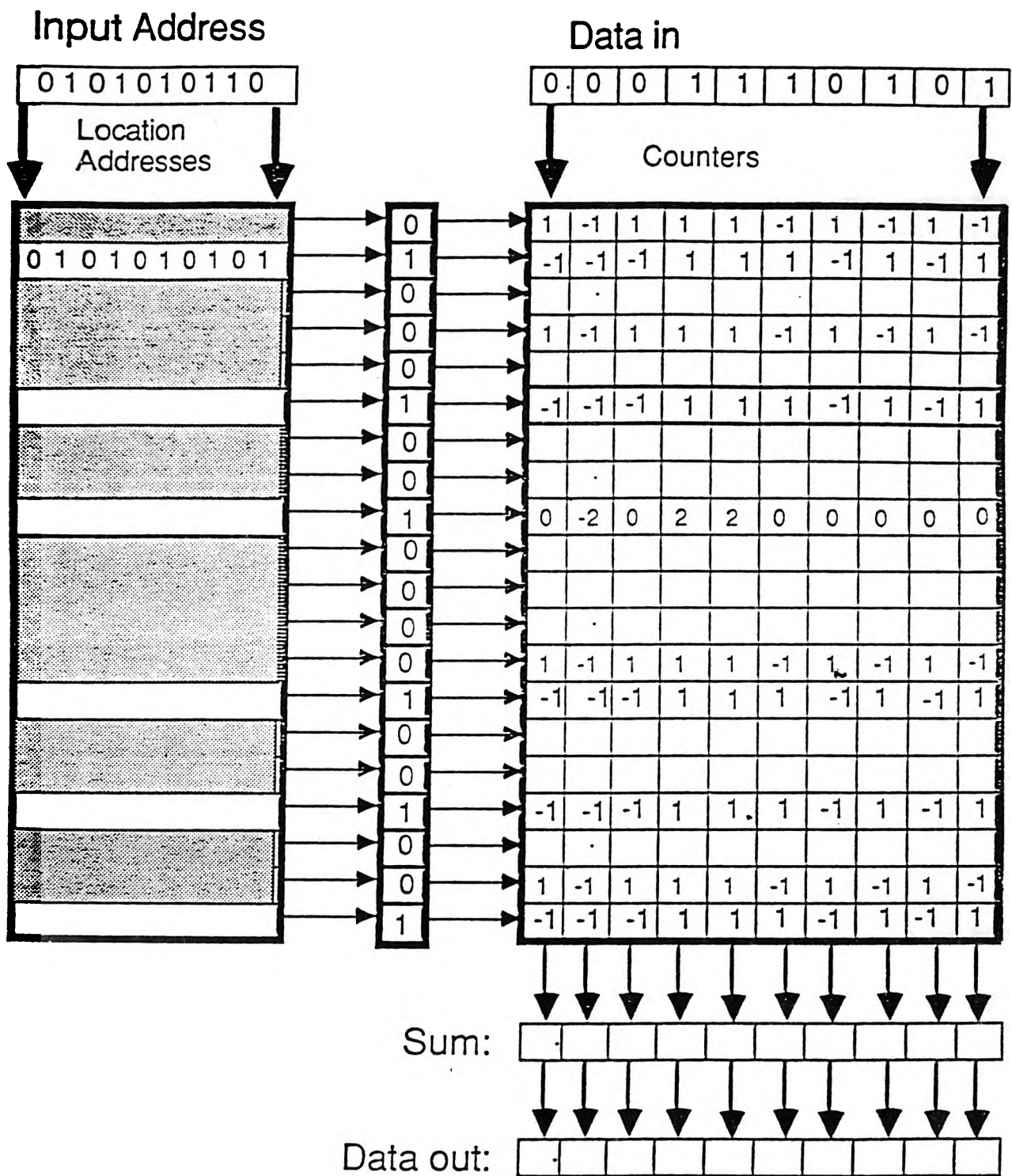
Data in

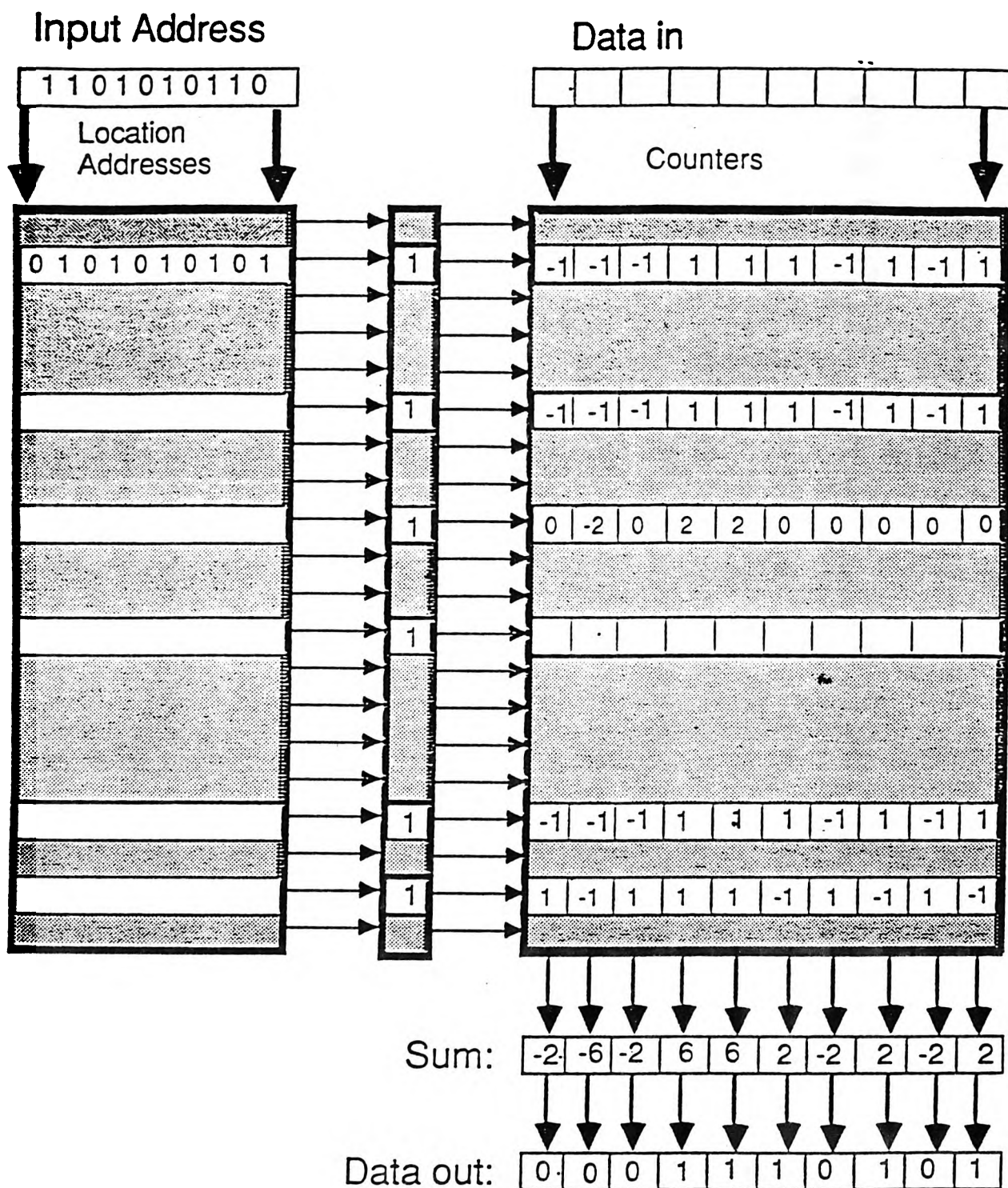
Location
Addresses

Counters









PROJECT: ADVANCED ALGORITHMS AND ARCHITECTURES

OBJECTIVE:

- Explore and develop new algorithms and architectures for solving large-scale NASA scientific problems

Principals at RIACS:

George Adams, RIACS
John Bruno, UCSB
Tony Chan, UCLA
Merrell Patrick, Duke
Michael Raugh, RIACS (Project
Manager)

NASA Collaborators:

David Bailey, NAS
Sanford Davis, Fluid Mechanics
Harvard Lomax, CFD
Harry Partridge, Chemistry
Ken Stevens, Comp. Research

MULTIGRID ALGORITHMS AND HYPERCUBE ARCHITECTURES

(An Advanced Algorithms and Architectures Project)

PARALLEL IMPLEMENTATIONS OF MULTIGRID

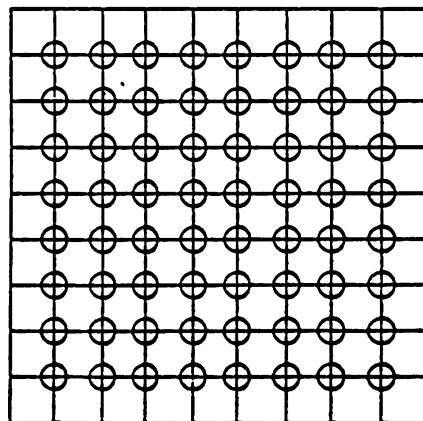
- Multigrid optimal for many partial differential equations
- Hypercube architectures near-optimal for multigrid
- Initial studies show promise for CFD

FUTURE DIRECTIONS

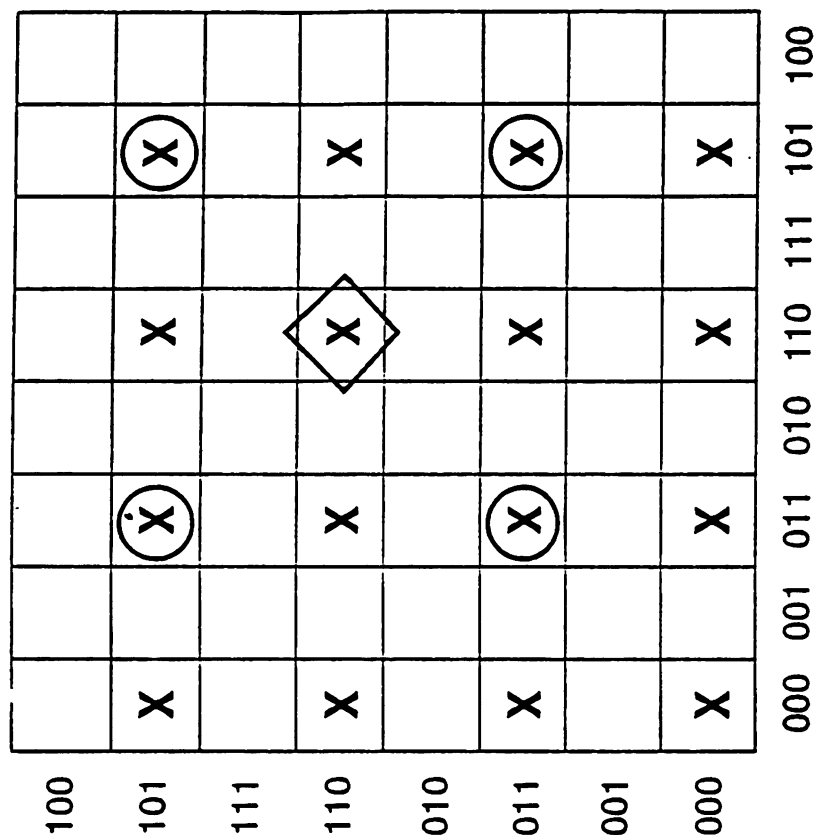
- Develop parametric models
- Establish programming principles
- Guide design of hypercube supercomputer for CFD

MAPPING OF GRID POINTS TO PROCESSORS USING BINARY REFLECTED GRAY CODE

Model Problem:
Driven Cavity
 (Steady State Stream
 Vorticity Formulation of
 Navier-Stokes Equations)



Grid Points for 2-D Problem



Schematic Representation of Hypercube Processors

FFT AND NN-MESH ON HYPERCUBES

(An Advanced Algorithms and Architectures Project)

HYPERCUBE IMPLEMENTATIONS:

- Natural map optimal for FFT but poor for NN-mesh (i -th point mapped to i -th processor)
- Gray code map optimal for NN-mesh (adjacent points mapped to adjacent processors)
- Binary Reflected Gray Code map optimal for NN-mesh and good for FFT

CHAN'S COMMUNICATION MODEL

- Predicts best map for given application
- Example: Use BRGC for NN-mesh applications; shuffle to and from natural map only if more than two FFTs will be performed
- Note: NN-mesh mapping with BRGC also good for Multigrid, Cyclic Reduction, Sorting

IMAGE CONTOUR EXTRACTION

Find boundaries between light and dark regions of unevenly lit image.

**Break image into regions: a) compute thresholds for each region,
b) reconcile boundaries.**

Code runs on Sequent Balance 21000 and on Intel hypercube.

How to partition into regions to balance load in Phase (a)?

How to reconcile boundaries to balance communication in Phase (b)?

What performance monitoring tools aid the programming of these phases?

How fast can image contours be extracted by this method?

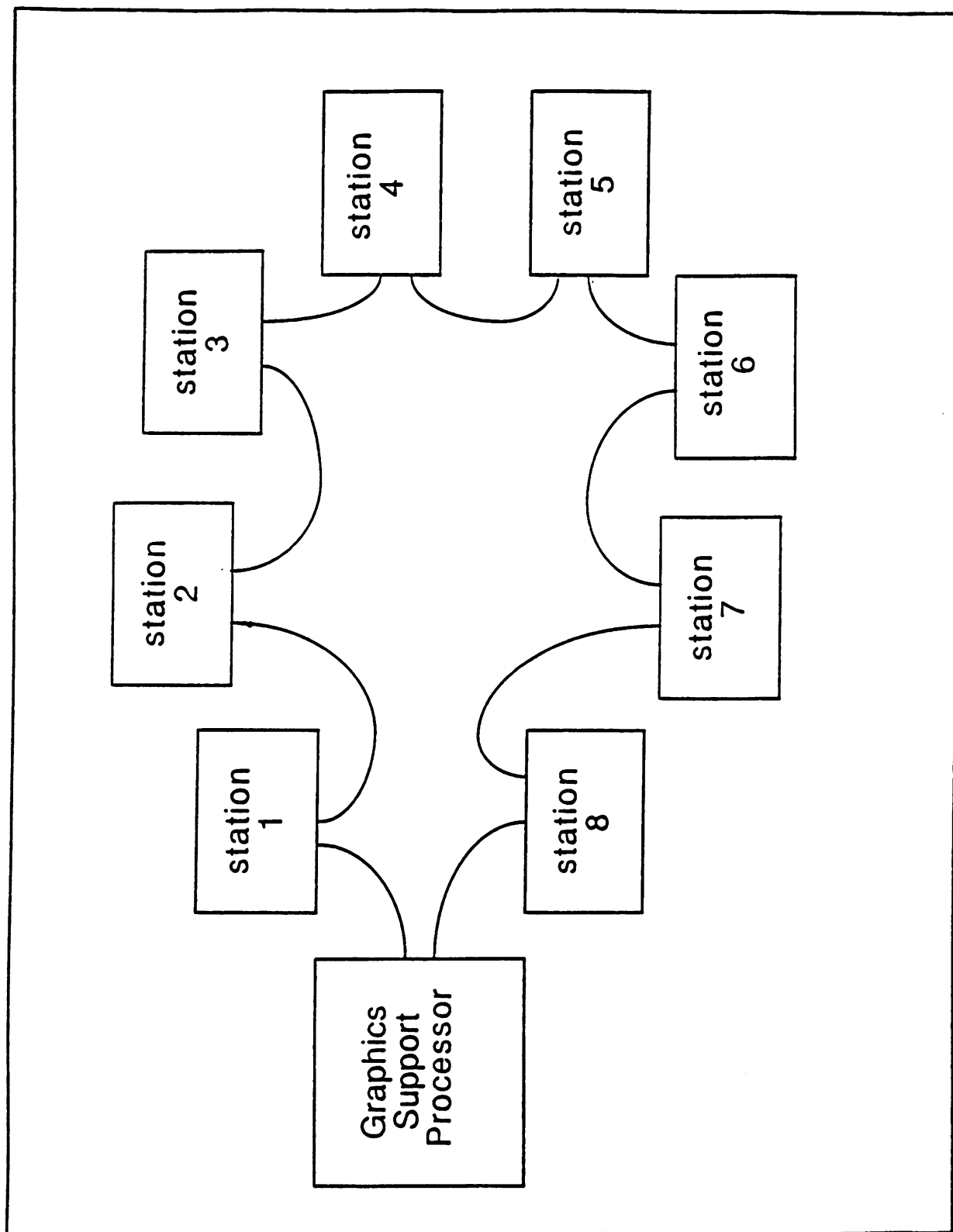
NETWORK PROTOCOLS

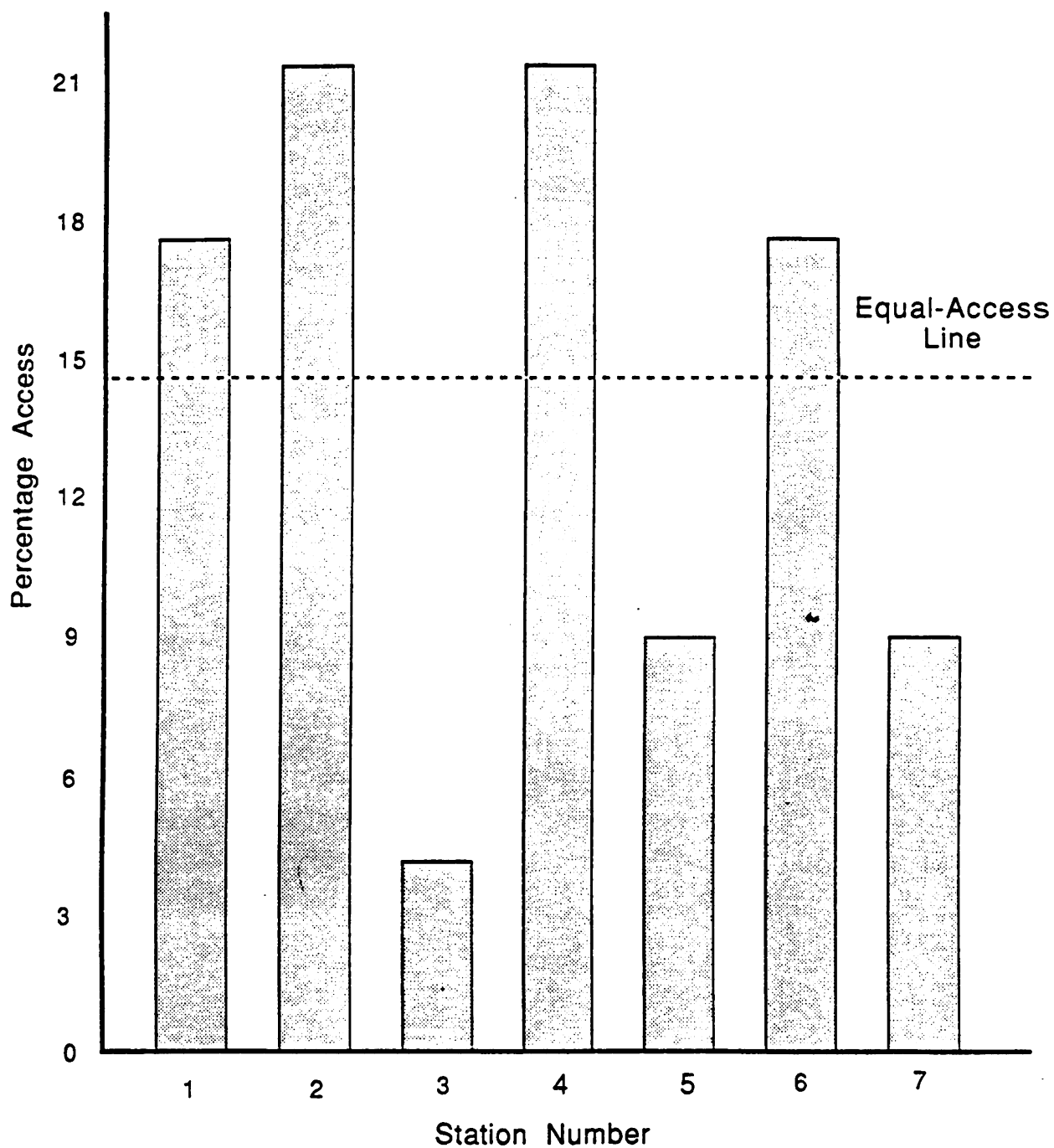
- **Fiber Distributed Data Interface (FDDI) is an ANSI draft proposed standard for a 100 Megabit per second fiber-optic token ring**
- **FDDI is a candidate media access protocol for the Space Station**
- **Complexity of FDDI timed token protocol necessitates analytic justification of performance claims presented in standards documents**
- **Several claims have been analytically established as a result of this project**
- **Also have shown that, under some circumstances, the FDDI claim of equal access to all stations on the ring is not valid**

The next two figures pertain to the FDDI protocol study.

The first figure shows 8 workstations connected on a ring to a graphics processor. The FDDI protocol could be used if the ring is fiber optic.

The second figure shows the results of a simulation study of FDDI. Under certain (reproducible) load conditions, where message length is long enough to delay the token at some stations, the stations do not obtain equal access to the ring. FDDI parameters must be set within allowable ranges to guarantee the equal-access property.



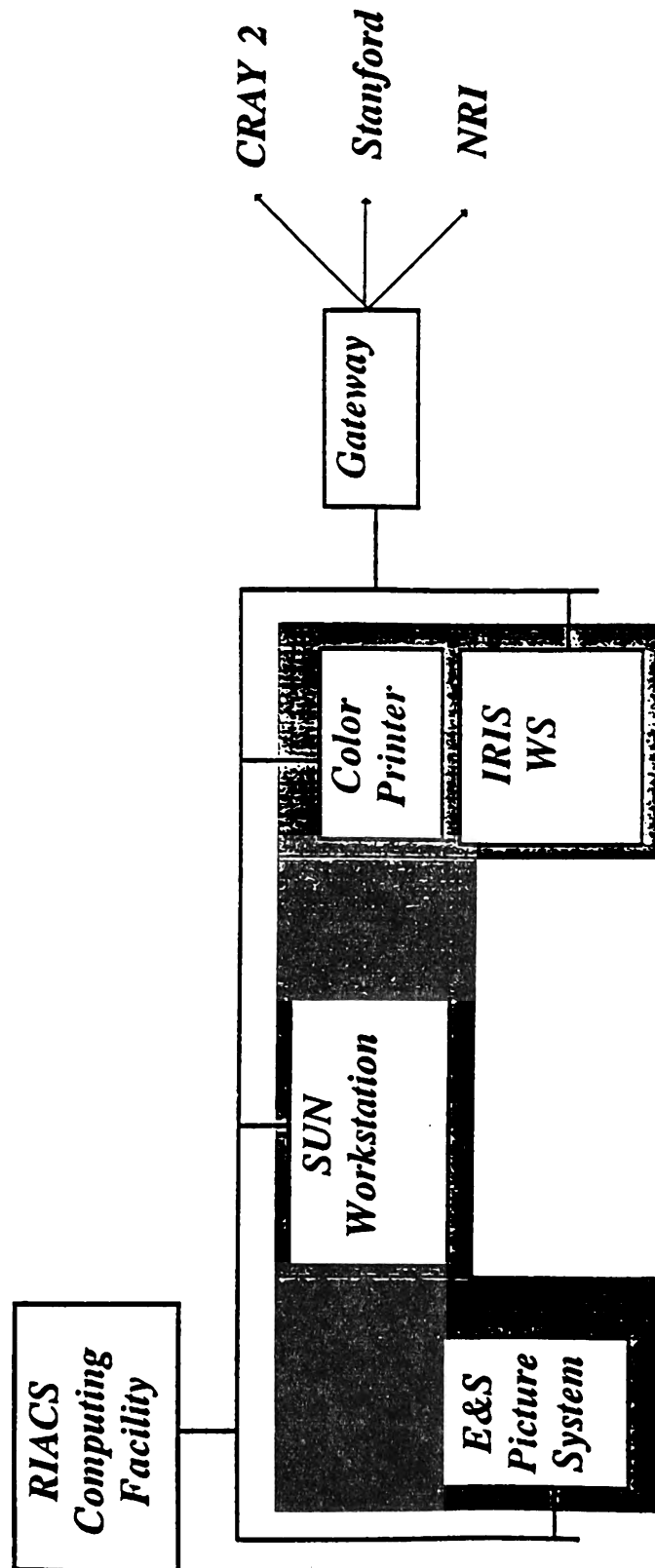


Fairness of Channel Access for FDDI High Bandwidth Token Ring

SCIENTIST'S WORKBENCH

- Support scientific investigation from problem formulation through computation solutions to publication
- Initial step towards *Scientist's Aide*
- In collaboration with working scientists:
 - Develop usage scenarios
 - Define functions needed (e.g. graphics, software development environment, remote control of supercomputations, symbolic math)
 - Integrate hardware and software
 - Use in advanced scientific research
- Iterative process

INITIAL SCIENTIST'S WORKBENCH



MULTIMEDIA CONFERENCING AND COLLABORATIVE RESEARCH

- **Networking and Workstations Provide Tools to Support Collaborative Research**
- **Computer Supported Real Time Multimedia Conferencing Available in Prototype**
- **Questions as to Required Features and Best Ways to Utilize**
 - **Use Scientist's Workbench Environment to Evaluate**
 - **Collaborative with Stanford and SRI**

INTERAGENCY RESEARCH INTERNET

- **Interconnection of Agency Funded Networks to Allow Cost-Effective Sharing of Network and Computing Resources, and Facilitate Collaborative Research**
- **RIACS Assisting FCCSET Network Working Group to Plan and Implement the Interconnection**

TELESCIENCE TESTBED

- Need for Rapid Prototyping Capability to Evaluate Advanced Information Technologies and Their Role in Space Station and the Space Station Information System
- RIACS Heading Working Group to Plan for Such an Environment
- Proposal being Drafted to Code E
 - Ten Universities Involved to Form Distributed Testbed
 - RIACS to Organize and Manage

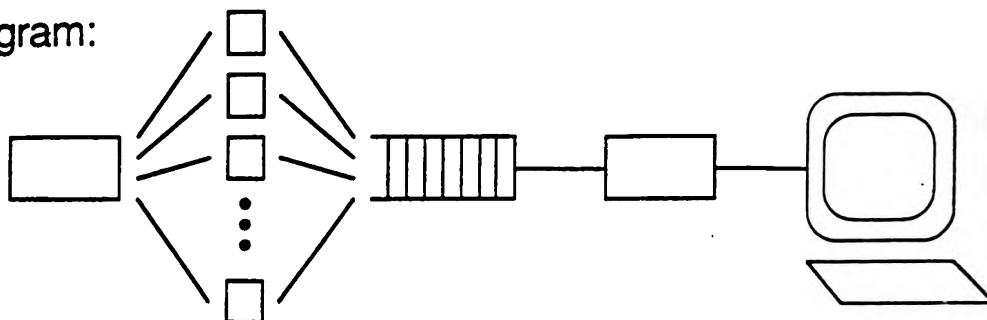
This slide depicts a style and language for writing parallel programs. The top third is a process-level block diagram of a typical concurrent program. This shows an array of computation processes (vertical stack of boxes) receiving pieces of work from a ticket server and feeding results to a queue manager for subsequent display.

The middle portion shows some of the program to implement the block diagram. The language is Concurrent C, developed at AT&T Bell Labs and implemented in a translator at RIACS.

The third portion shows how this concurrent program "plugs into" and interactive graphics application running on a color workstation. The inputs to the program are provided from a user-interface "control panel" and the output drives a graphics window.

Parallel Programming Languages

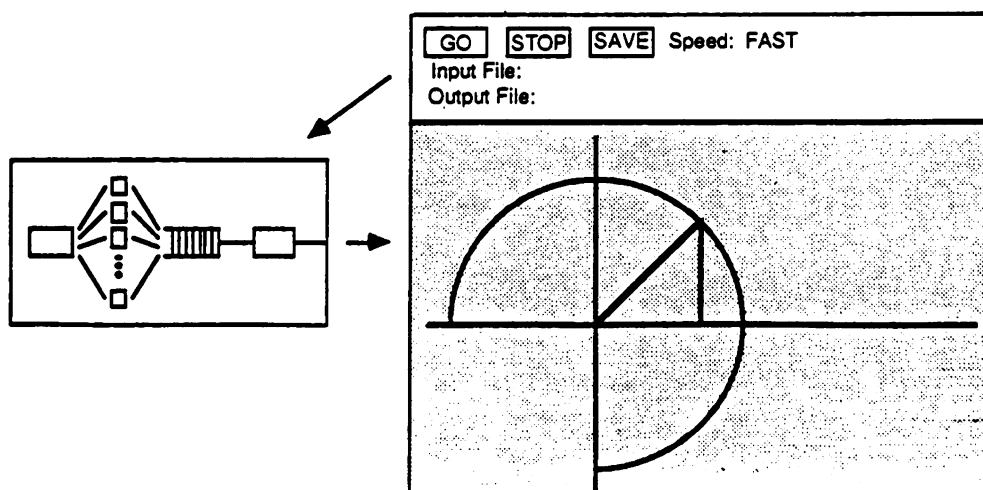
Block Diagram:



Concurrent C program:

```
ticket = create ticket(N);  
for ( i=0 ; i<N i ;++ )  
    compute[i] = create compute(i,ticket,display);  
...  
process body compute ( i, tick, disp)  
{  
    while ( tick.next < N ) {  
        ...  
        disp.put();  
    }  
}
```

Interactive Graphics-oriented Application:



A PROPOSAL TO ESTABLISH

A

NASA CENTER OF EXCELLENCE

IN

SPACE DATA INFORMATION SCIENCES

(CESDIS)

OVERVIEW

- o OSSA DATA PROBLEMS**
- o THE USRA/U. MD. PROPOSAL, MANAGEMENT, BUDGET, ISSUES**
- o COMMENTS AND RECOMMENDATIONS**

FUTURE INSTRUMENTS AND THEIR DATA RATES (MB/s)*

SAR	-	300 MB/s
HIRIS	-	160 MB/s
TM/WLA	-	85 MB/s
TIMS	-	30 MB/s
SIRTF	-	10 MB/s
MODIS	-	10 MB/s
HRSO	-	5 MB/s
FUSE	-	2 MB/s
Sp. TELE.-	.2 MB/s	(800 GB/YR) OR (400 O.D. PLATTERS)
TOTAL	603 MB/s	OR 50,000 TAPES/DAY OR 20-YEAR NSSDC HOLDINGS

* 1 MB/s = 75 TAPES/DAY AT 6250 BPI OR 27,375 TAPES/YEAR

OBSERVING SYSTEMS OVERWHELMING INFORMATION PROCESSING SYSTEMS

DATA VOLUME: SENSOR DATA RATES GROWING $\sim N^4$ (10^{13} - 10^{15} B/YR); HIGH SPEED STORAGE/ACCESS
TECHNOLOGIES GROWING (10^9 - 10^{12} B/YR); TYPICAL SCIENCE SCENARIO NEEDS
TO HANDLE 1000 TAPES/INSTRUMENT

INFORMATION SYSTEMS:

DISTRIBUTED MASSIVE ARCHIVES, HETEROGENEOUS ENVIRONMENTS, MULTI-
SPECTRAL/SPATIAL DATA STREAMS, COORDINATED OBSERVATIONAL CAMPAIGNS

COMPUTATIONAL ANALYSIS:

SATELLITE MEASUREMENTS REQUIRE COMPLEX INTERPLAY BETWEEN DATA AND
THEORETICAL MODELS, MULTI-DISCIPLINARY SYSTEMS, INTERACTIVE IMAGE AND
GRAPHICS SYSTEMS, MELDING VERY LARGE INFORMATION BASES

NASA ABILITY TO DEAL WITH THE DATA SITUATION RAISING NUMEROUS CONCERNS IN SCIENCE COMMUNITY

WHAT IS NASA DOING ABOUT DATA PROBLEMS?

- o COLLECTING LIMITED DATA SAMPLES FROM HIGH DATA RATE INSTRUMENTS (DUTY CYCLES)**
- o STORING AND PERMANENTLY ARCHIVING ALL AVAILABLE DATA UNTIL TECHNOLOGY CATCHES UP**
- o DEVELOPING MULTIPLE PILOT DISCIPLINE DATA SYSTEMS TO ADDRESS CURRENT DATA PROBLEMS**
- o CONTRACTING OUT FOR DATA SYSTEMS BASED ON EXISTING TECHNOLOGIES TO MEET SPECIFIC FLIGHT PROGRAMS**

DIFFICULTIES IN DEALING WITH SPACE SCIENCE DATA PROBLEMS STEM FROM:

- o SEVERE LACK OF SKILLED, IN-HOUSE EXPERTISE**
 - NASA'S SCIENTIFIC EXPERTISE DOES NOT ADEQUATELY ENCOMPASS HIGHLY SPECIALIZED DATA SYSTEMS AND TECHNOLOGIES**
 - FLOOD OF COMPETITIVE, PROFESSIONALLY EXCITING POSITIONS (NSF, DOD AND INDUSTRY/STATE CONSORTIUMS) SERIOUSLY IMPACTING ABILITY TO RECRUIT OR HOLD FIRST-RATE TALENT**
- o UNIVERSITY COMPUTATIONAL SCIENCES NOT ADDRESSING FUTURE OSSA DATA PROBLEMS**
 - NASA'S SPACE DATA PROBLEMS UNKNOWN IN MOST COMPUTER SCIENCE DEPARTMENTS**
 - LITTLE COMMERCIAL PAY-OFF TO INDUSTRY FOR NASA-UNIQUE PROBLEMS**
- o EXTREMELY COMPLEX PROBLEM CUTTING ACROSS SCIENTIFIC BOUNDARIES WITH IMMATURE EMERGING TECHNOLOGIES**

HOW DO WE SOLVE THE DATA PROBLEMS?

WE NEED TO:

- o NEED TO BRING TO BEAR ADVANCED TECHNOLOGIES AND STATE-OF-THE-ART SYSTEMS EQUAL TO DEALING WITH THE CHALLENGE

(MEANS ACQUIRING STATE-OF-THE-ART MASS STORAGE PROCESSING SYSTEMS,
DEVELOPING AUTOMATED INTELLIGENT ANALYSIS SYSTEMS, ETC.)

- o FOCUS UNIVERSITY AND INDUSTRY INFORMATION SCIENCE RESEARCH ONTO NASA'S RELATED DATA PROBLEMS

- o SELECTIVELY BROADEN OUR LIMITED POOL OF TALENT IN COMPUTATIONAL AND INFORMATION SCIENCES

- o CONTINUE SUPPORTING THE PILOT DATA SYSTEMS PROGRAMS AND OTHER DATA TECHNOLOGY TEST BEDDING STUDIES

- o BEGIN BY MAKING A LONG-TERM RESEARCH INVESTMENT IN THE INFORMATION SCIENCES TAILORED TO OSSA'S DATA PROBLEMS

**NASA/GSFC HAS RECEIVED AN
INNOVATIVE PROPOSAL FROM USRA AND THE U. OF MARYLAND
TO ESTABLISH A
CENTER OF EXCELLENCE IN
SPACE DATA INFORMATION SCIENCES
(CESDIS)
TO DEAL WITH NASA'S LONG-TERM DATA PROBLEMS**

CESDIS PROPOSES TO:

- o ESTABLISH A "CONSORTIUM" OF ACADEMIA AND INDUSTRY -
 - COMMITTED TO SPECIALIZED INFORMATION SCIENCE RESEARCH TAILORED TO NASA'S LONG-TERM SPACE DATA PROBLEMS
- o CREATE "CRITICAL MASS EFFECT" BY -
 - UNITING A LARGE NUMBER OF UNIVERSITY AND INDUSTRY EXPERTS IN COMPUTER SCIENCE, DATA SYSTEMS IMAGE AND SIGNAL PROCESSING TO WORK WITH NASA SCIENTISTS ON SPACE DATA PROBLEMS
- o UTILIZE "HIGH TECH" RESOURCES -
 - MAKE AVAILABLE TO CESDIS INVESTIGATORS ACCESS TO NASA SUPERCOMPUTERS, NETWORKS, PARALLEL PROCESSING SYSTEMS, MEGA DATA SYSTEMS, IMAGE ANALYSIS SYSTEMS, ROBOTS, ETC.

THE CENTER OF EXCELLENCE WILL:

- o HOUSE AT GSFC A "TELE-INSTITUTE" WITH MEMBERS NETWORKED FROM THEIR HOME INSTITUTIONS TO EACH OTHER AND APPROPRIATE NASA CENTERS
- o ENCOURAGE SUBSTANTIAL ON-SITE INTERACTIONS WITH THE MOST QUALIFIED ACADEMIC AND INDUSTRIAL EXPERTS IN THE COUNTRY
- o PROJECT NASA COMPUTATIONAL RESEARCH INTERESTS AND NEEDS INTO UNIVERSITY DEPARTMENTS AND INDUSTRY IR&D
- o ESTABLISH WORKING-LEVEL TIES WITH UNIVERSITY GRADUATE STUDENTS AND FACULTY TO ENSURE A POOL OF TALENT FOR NASA'S FUTURE
- o CREATE A FOCUS OF RESEARCH EXCELLENCE IN INFORMATION SCIENCE AT GSFC

USRA/UNIVERSITY OF MARYLAND PROPOSAL HIGHLIGHTS:

- ADMINISTRATION BY USRA (FUNDING AND SUBCONTRACTS), MANAGED BY DIRECTOR, U/MD
- DEPARTMENT OF COMPUTER SCIENCES UNIVERSITY OF MARYLAND WILL ESTABLISH FULL TENURED PROFESSORSHIP FOR DIRECTOR; APPOINTMENT SUBJECT TO CONCURRENCE OF NASA; UNIVERSITY OF MARYLAND PROVIDES 50% OF DIRECTOR'S ACADEMIC YEAR SALARY
- NASA-SUPPORTED FULL FACULTY TEACHING APPOINTMENTS AT U.S. UNIVERSITIES; APPROXIMATELY 40% OF YEAR ON-SITE AT GODDARD; NASA/UNIVERSITY SHARED 5-YEAR ROLLING APPOINTMENTS
- INDUSTRY PARTICIPATION ON EQUAL BASIS WITH UNIVERSITIES WITH NO SALARIES, NO PROPRIETARY RIGHTS TO RESEARCH RESULTS
- UNIVERSITY AND INDUSTRY PARTICIPATION THROUGH PEER-REVIEWED PROPOSAL PROCESS
- CESDIS ADVISORY BOARD CONSISTING OF ALL COOPERATING UNIVERSITIES, INDUSTRIAL MEMBERS (2/3) AND GOVERNMENT (NASA OR OTHERS) (1/3) FOR SCIENCE OVERSIGHT
- ACCESS TO NASA/GSFC COMPUTING RESOURCES

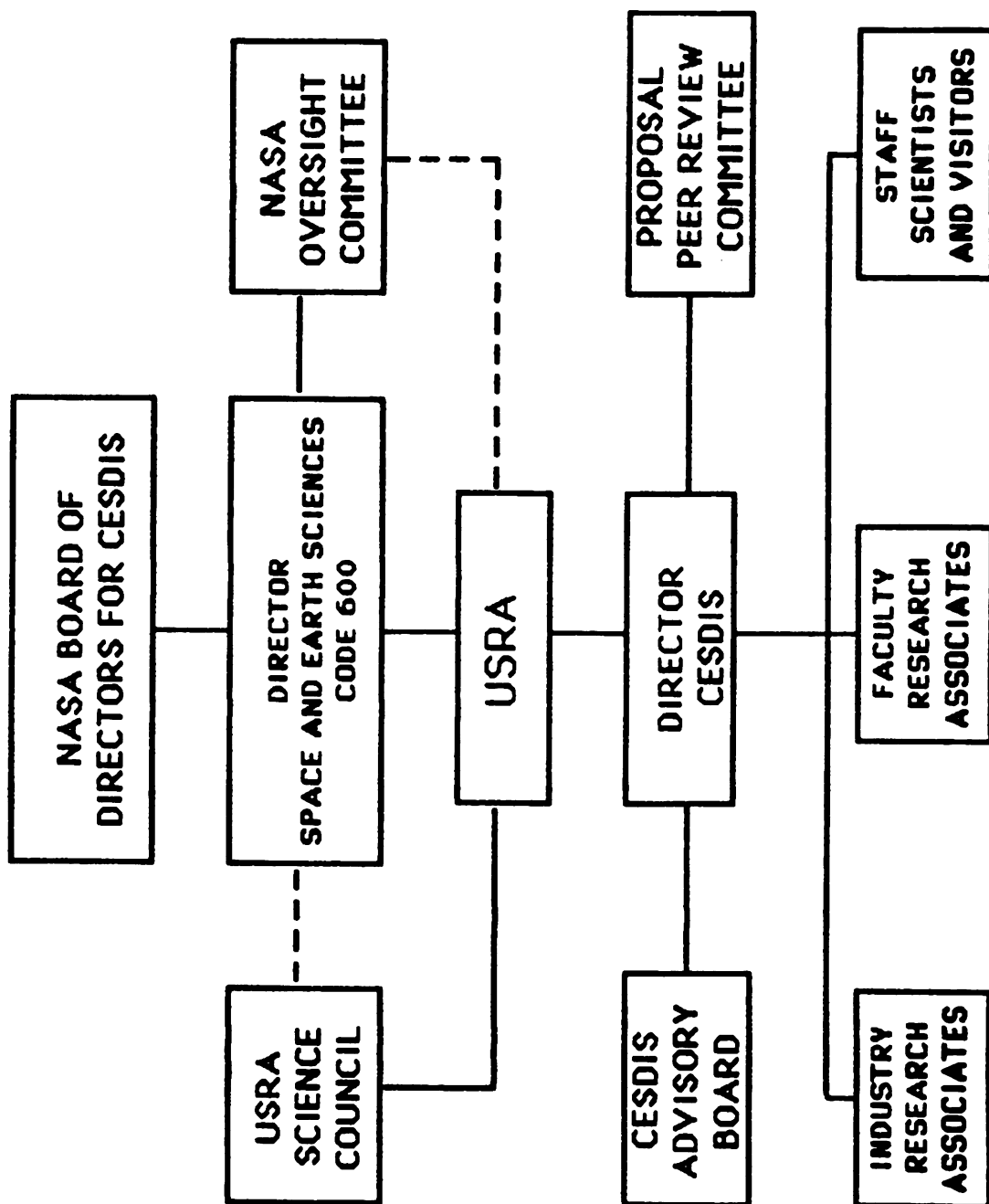
UNIVERSITY MEMBERSHIP SELECTION PROCESS

- o DIRECTOR OF CESDIS IDENTIFIES RESEARCH PROGRAM AREAS WITH CONCURRENCE OF NASA BOARD OF DIRECTORS
- o USRA ISSUES CALL FOR PROPOSALS
- o DIRECTOR OF CESDIS ESTABLISHES PEER REVIEW COMMITTEE---UNIVERSITY/INDUSTRIAL/GOV'T.
- o PEER REVIEW COMMITTEE RANKS PROPOSALS -
 - QUALITY
 - INSTITUTIONAL EXPERTISE
 - UNIVERSITY COMMITMENT
- o SELECTION BY DIRECTOR, CESDIS, CONCURRENCE OF NASA OVERSIGHT COMMITTEE
- o SUBCONTRACT(S) AWARDED BY USRA, GSFC TECHNICAL MONITORS

POTENTIAL RESEARCH AREAS

- o MASSIVE DATA BASE SYSTEMS AND ARCHITECTURE STUDIES
- o IMAGE DATA COMPRESSION FOR GROUND AND ON-BOARD PROCESSING
- o HIGH SPEED (10^2 -- 10^3 MB/S) ON-LINE DATA ACCESS SYSTEMS
- o CONCURRENT PROCESSING APPLICATIONS
- o RESEARCH MISSION DATA SYSTEMS SUPPORT: ST, HRSO, MODIS, EOS
- o PATTERN RECOGNITION FOR INFORMATION ANALYSIS
- o EXPERT SYSTEMS AND NATURAL QUERYING LANGUAGES
- o ROBOTICS AND VISION

OPERATING RELATIONSHIPS



OPERATING CONCEPT

<u>UNITS</u>	<u>COMPOSITION</u>	<u>FUNCTIONS</u>
NASA BOARD OF DIRECTORS FOR CESDIS	<ul style="list-style-type: none"> - HEADQUARTERS AA's (E, R) - GSFC DIRECTORS OF (600, 700, 500) - OTHER NASA CENTERS - NSF - CHAIRED, GSFC DEPUTY DIRECTOR 	<ul style="list-style-type: none"> - APPROVE RESEARCH AREAS, PROGRAM PLANS, POLICIES - GENERAL REVIEW OF ACCOMPLISHMENTS, ISSUES, BUDGETS
NASA OVERSIGHT COMMITTEE	<ul style="list-style-type: none"> - GSFC LABORATORY AND DIVISION CHIEFS - HEADQUARTERS PROGRAM MANAGERS - OTHER NASA CENTERS, DIVISION CHIEFS - CHAIRED, CHIEF, SPACE DATA & COMPUTING DIVISION, GSFC 	<ul style="list-style-type: none"> - RECOMMENDS RESEARCH AREAS, POLICIES - REVIEWS PROGRAMS, PROGRESS, VISITOR ACTIVITIES, WORKSHOPS, LECTURES
CESDIS ADVISORY BOARD	<ul style="list-style-type: none"> - PARTICIPATING UNIVERSITY AND INDUSTRY DEPARTMENT HEADS - AD HOC NASA REPRESENTATIVES (NASA AND OTHER FEDERAL AGENCIES) - CHAIRED BY ELECTED MEMBER 	<ul style="list-style-type: none"> - GUIDANCE ON MANAGEMENT, OPERATIONS WITH PARTICIPATING MEMBERS
CESDIS PROPOSAL PEER REVIEW COMMITTEE	<ul style="list-style-type: none"> - UNIVERSITIES, INDUSTRY, GOV'T - SELECTED BY CESDIS DIRECTOR 	<ul style="list-style-type: none"> - REVIEW AND RANK PROPOSALS - RECOMMEND TO CESDIS DIRECTOR
USRA SCIENCE COUNCIL	<ul style="list-style-type: none"> - STANDING USRA COMMITTEE - AD HOC NASA MEMBERSHIP 	<ul style="list-style-type: none"> - CONDUCTS PERIODIC REVIEW OF PERFORMANCE, RELATIVE CONTRIBUTIONS - REPORTS TO USRA BOARD OF TRUSTEES - PROVIDE NASA SPECIFIC WRITTEN APPRAISALS - CONDUCT TRIENNIAL PEER REVIEW, AS REQUESTED

EXAMPLES OF POLICY/BUDGET ISSUES

- o ACCEPTS NO MORE THAN XZ NON-NASA FUNDING SUPPORT**
- o TOTAL SUPPORT NOT MORE THAN YZ OF BASE INSTITUTIONAL SUPPORT**
- o VISITING MEMBERS NOT MORE THAN TWO YEARS**
- o FRA's SHALL ACCEPT NO MORE THAN XXZ NON-NASA SUPPORT**
- o WHAT PERCENTAGE OF RESOURCES ALLOCATED TO CESDIS, FRA's, IRA's?**
- o CAN CESDIS RELEASE ANY SOFTWARE AND HARDWARE DESIGNS TO INDUSTRIAL MEMBERS?**
- o RELATIVE EFFORTS BETWEEN INFORMATION SCIENCE AND INFORMATION APPLICATIONS**

USRA AND GSFC ESTABLISHED A PLANNING COMMITTEE

MEMBERSHIP

VICTOR BASILI.....UNIVERSITY OF MARYLAND
SHELTON ALEXANDER.....PENNSYLVANIA STATE UNIVERSITY
BRUCE ARDEN.....PRINCETON UNIVERSITY
PETER BANKS.....STANFORD UNIVERSITY
RALPH BERNSTEIN.....IBM
ROBERT SPEARING.....GODDARD SPACE FLIGHT CENTER
MOUSTAFA CHAHINE.....JET PROPULSION LABORATORY
PETER DENNING.....RIACS
BERNARD GALLER (CHAIR).....UNIVERSITY OF MICHIGAN
ANTHONY HEARN.....RAND CORPORATION
EUGENE ISAACSON.....NEW YORK UNIVERSITY
LARRY JODSAAS.....CONTROL DATA CORPORATION
DONALD JOHNSON.....UNIVERSITY OF WISCONSIN
ROBERT DORFMAN.....UNIVERSITY OF MARYLAND
ROBERT KURUCZ.....SMITHSONIAN ASTROPHYSICAL OBSERVATORY
LOUIS LANZEROTTI.....AT&T (BELL LABS)
ROBERT MCPHERRON.....UNIVERSITY OF CALIFORNIA AT LOS ANGELES
JOHN QUANN.....GODDARD SPACE FLIGHT CENTER
ETHAN SCHREIER.....SPACE TELESCOPE SCIENCE INSTITUTE
GERALD SOFFEN.....GODDARD SPACE FLIGHT CENTER
JAMES TRAINOR.....GODDARD SPACE FLIGHT CENTER
MIKE MCGREEVY.....NASA/HQ/OAST
CALDWELL MCCOY.....NASA/HQ/OSSA

GSFC DISCUSSIONS WITH ACADEMIC AND INDUSTRY LEADERS AND THE CONCLUSIONS OF THE PLANNING COMMITTEE INDICATE:

COMMITTEE:

- "HIGHLY INNOVATIVE AND HOLDS GREAT PROMISE FOR IMPROVING NASA SCIENTIFIC DATA AND INFORMATION SCIENCE PROGRAM"
- "PROPOSAL MAKES SENSE IN SEVERAL WAYS:
 - o ADDRESSES THE PROBLEM OF SCARCITY OF COMPUTER SCIENTISTS
 - o CONSISTENT WITH EMERGING TECHNOLOGICAL CAPABILITIES
 - o TAKES ADVANTAGE OF LOCAL STRENGTH OF UNIV. OF MARYLAND
 - o DEEPENS INTERACTION BETWEEN GSFC AND COMPUTER SCIENCE RESEARCH ACTIVITIES AT OTHER UNIVERSITIES AND INDUSTRY."

**ACADEMIC
AND INDUSTRY:**

- INTEREST EXPRESSED BY COLUMBIA, HARVARD, MIT, NYU, U/VA, RPI, GEORGE MASON, U/MD, JOHNS HOPKINS, CONTROL DATA, AND DIGITAL EQUIPMENT CORPORATION (DEC)

WHAT'S ADVANTAGE TO GSFC?

- CODE 600:** DIRECT SUPPORT TO ALL THE LABORATORIES THROUGH ADVANCED ANALYSIS TECHNIQUES AND SYSTEMS, DATA BASE SYSTEMS, DATA MANIPULATION, ADVANCED SOFTWARE SYSTEMS AND MISSION ANALYSIS SUPPORT. INTERDISCIPLINARY SCIENCE ENHANCED. EXTENDS MODELING TECHNIQUES. ADVANCED IMAGE ANALYSIS AND GRAPHICS. BETTER SCIENCE OVERALL.
- CODE 700:** ON-BOARD PROCESSING AND DATA COMPRESSION TECHNIQUES FOR ADVANCED INSTRUMENT DESIGN AND ROBOTIC INSTRUMENT SERVICING
- CODE 500:** REQUIRES HIGHLY FOCUSED, SHORTER TERM RESEARCH IN HIERARCHIAL EXPERT SYSTEMS, KNOWLEDGE-BASED DEVELOPMENT, MACHINE LEARNING, DATA STRUCTURES, ETC. WOULD PROVIDE NEEDED UNIVERSITY SUPPORT TO PROGRAM NEEDS
- CODE 200:** POSSIBLE HETEROGENEOUS DATA BASES, DATA STORAGE AND MANIPULATION TECHNIQUES. ADVANCED NETWORKING.
- CODE 400:** ADVANCED FLIGHT SOFTWARE TECHNIQUES
- CENTER:** REPUTATION AND STATURE IN SCIENCE COMMUNITY

SUMMARY

- o THE CENTER OF EXCELLENCE PROVIDES NASA/GSFC WITH DIRECT ACCESS TO THE ONLY COMMUNITY THAT CAN SOLVE THE OSSA DATA PROBLEMS
- o GODDARD IS PREPARED TO DEVOTE THE IN-HOUSE RESOURCES NECESSARY TO MANAGE AND SUPPORT THE CENTER OF EXCELLENCE
- o CONCEPT ESTABLISHES A MAJOR NEW RESEARCH APPROACH TO UNIVERSITY AND INDUSTRIAL RELATIONS;
- o DEVELOPS MECHANISM TO ATTRACT HIGHLY-TRAINED COMPUTER SCIENTISTS

APPENDIX A

MEMORANDUM OF UNDERSTANDING

between

The University of Maryland

and

The Universities Space Research Association

Purpose: This Memorandum of Understanding summarizes the points of agreement between the University of Maryland and the Universities Space Research Association (USRA) regarding the proposed Center of Excellence in Space Data and Information Sciences at NASA's Goddard Space Flight Center (GSFC).

Points of Agreement:

1. The search committee for the Director shall be a subcommittee of the planning committee for the Center of Excellence, and one of the representatives of the University of Maryland on the planning committee shall chair the search committee. In addition, a member of the Department of Computer Science will serve on the search committee and coordinate the search and selection activity with departmental review, including all normal university procedures.
2. The selection of the Director of the Center of Excellence must be approved by the University of Maryland, USRA, and NASA. It is expected that the selected individual will serve as Director for at least five years. The University of Maryland will provide a line in its budget for the Director, with academic year salary for the line.
3. The Director will be a tenured faculty member in the Computer Science Department at the University of Maryland. To serve as Director of the Center of Excellence, the selected individual will be given 50% release from the normal teaching load.

4. Fifty percent of the Director's academic year salary, all of the summer salary, and the pro-rata associated fringe benefits that are normally available to faculty members at the University of Maryland shall be reimbursed by USRA to the University of Maryland as compensation for the Director's responsibilities to the Center of Excellence.
5. If the selected Director requires reimbursement for the expense of relocating to the Washington area, USRA will bear the cost of the Director's moving expenses.
6. Annual salary adjustments will be negotiable between the Director and the University of Maryland. USRA will honor reasonable adjustments established by these negotiations.
7. The Department of Computer Science will further participate and support the research goals of the Center of Excellence through a contract between USRA and the University, with the Chairman of the Department of Computer Science serving as the manager of the contract. In addition to USRA's share of the salaries of the Director, half-time academic year support and full-time summer support will be provided for three University of Maryland, College Park, faculty members and three graduate students. These faculty members shall be designated as Staff Scientists in the Center of Excellence and shall hold joint appointments with the Center of Excellence and the appropriate academic department at the university. All joint appointments shall be made with the concurrence of the Director, the Department Chairman, and the Provost of the Division of Mathematics, Physical Sciences, and Engineering.

8. USRA's ability to reimburse the University of Maryland for a portion of the salary and fringe benefits of the Director is contingent upon continued funding for the Center of Excellence by NASA. USRA will exert best efforts to negotiate a contract with NASA that provides at least four and one half months (one academic year at half-time) of salary and fringe benefits for the Director in the event that NASA prematurely terminates the contract.
9. The specific terms of this agreement will be reviewed annually and may be modified by mutual written consent of the signing parties.

The University of Maryland



John S. Toll
President

The Universities Space
Research Association



Paul J. Coleman, Jr.
President

**CONCURRENT PROCESSING ALGORITHM DESIGN
(CPAD)**

**LOAD BALANCING
IN A PARALLEL PROCESSING ENVIRONMENT**

**MOKTAR SALAMA
JPL**

**NASA COMPUTER SCIENCES & DATA SYSTEMS WORKSHOP
NOVEMBER, 1986
WILLIAMSBURG, VIRGINA**

LOAD BALANCING

IN A PARALLEL PROCESSING ENVIRONMENT

What is Load Balancing?

- Parallel Processing: resources of several processors are brought together to share in solution of a single problem.
- Total solution is decomposed into "processes" that execute concurrently and communicate sparingly.
- If the processes require equal resources when run on an ensemble on n-processor \Rightarrow load-balanced computer.
- If not, then: speed of the ensemble of n-processors is that of the slowest processor (most heavily loaded) \Rightarrow load-imbalanced computer.

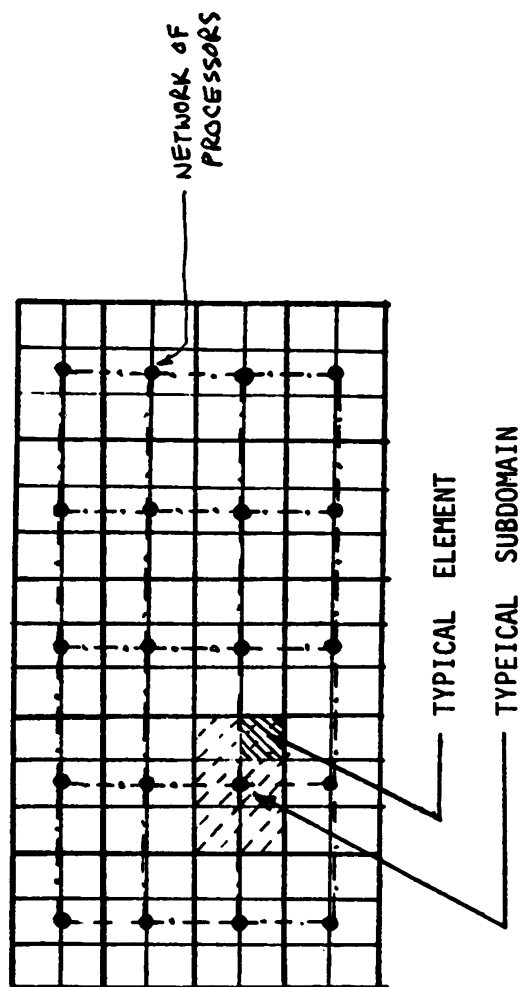
An optimal assignment problem

Factors Affecting Load Balancing

- Amenability of processes to uniform distribution (time to execute; precedence constraints, communication requirements, . . . etc).
- Topology of the ensemble (how many processors, communication topology, communication mechanism, . . . etc).

AN EXAMPLE OF LOAD BALANCING

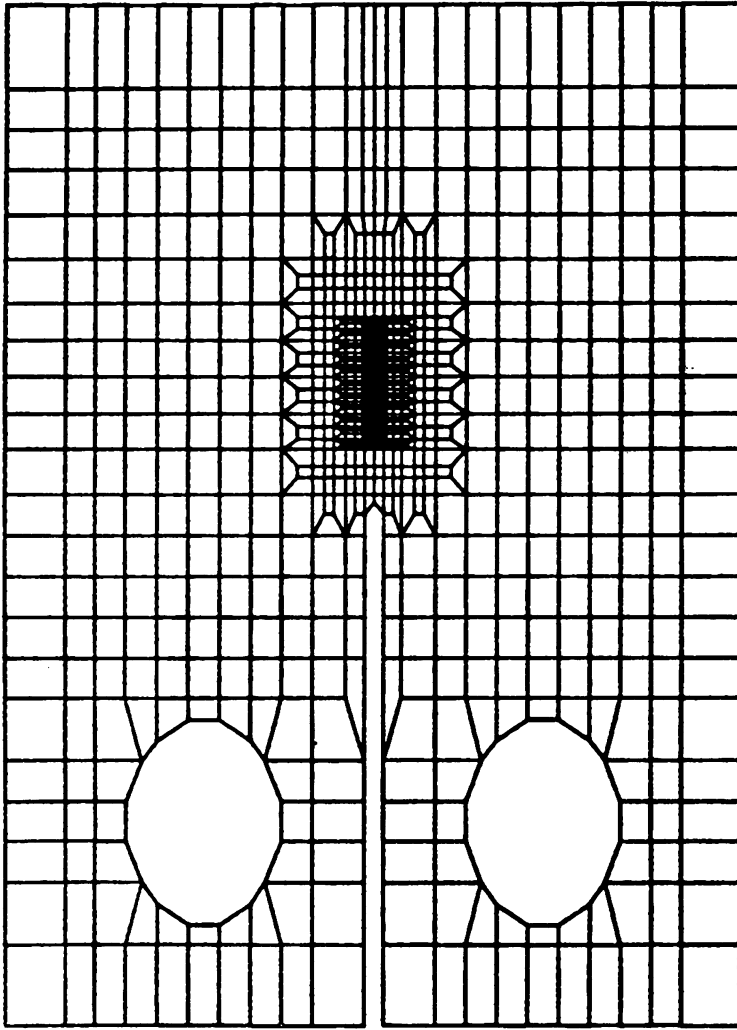
- o Regular domain, regular processor topology



- o Process = subdomain = task
- o Equal task distribution and communication; work load is balanced.

IMBALANCED PROBLEM

O IRREGULAR DOMAIN



- How to map the domain to processors is not obvious.
- SPEED of the ensemble of n-processors is that of the slowest (most loaded) processor.
- Needed; a methodology to balance load distribution (Computation + Communication).
- An intractable problem in combinatorial optimization; hence - heuristic.

THE SIMULATED ANNEALING ANALOGY

A HEURISTIC LOAD BALANCING APPROACH

- o In a body of matter, system's energy

$$E = \{(\text{Repulsive Forces}) + (\text{Attractive Forces})\}$$

In a parallel computer, comp. cost

$$E = \{(\text{Comp. Cost}) + (\text{Comm. Cost})\}$$

$$= \left\{ \sum_{i=1}^N (W_i)^2 + \frac{t_{\text{comm.}}}{t_{\text{comp.}}} \sum_{p < q} C_{pq} \right\}$$

W_i = Workload of processor, i

C_{pq} = Comm. cost between elements p and q

$t_{\text{comm.}}$ = Typical comm. time per element

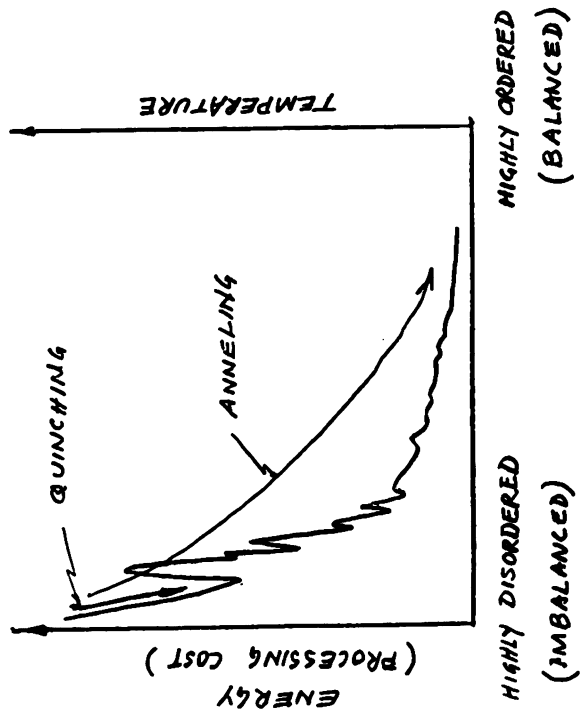
$t_{\text{comp.}}$ = Typical time for floating pt. oper/element

- o Positions assumed by atoms in a body determine the body's energy state.
Allocating elements to processors determine total processing cost.

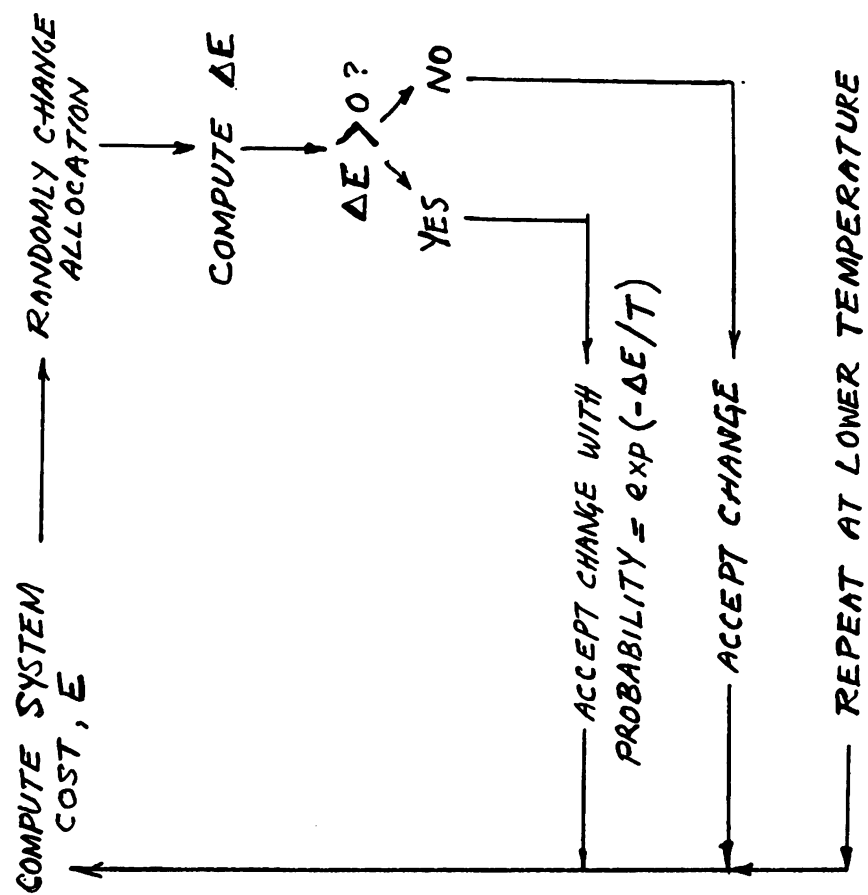
SIMULATED ANNEALING ANALOGY (CONT.)

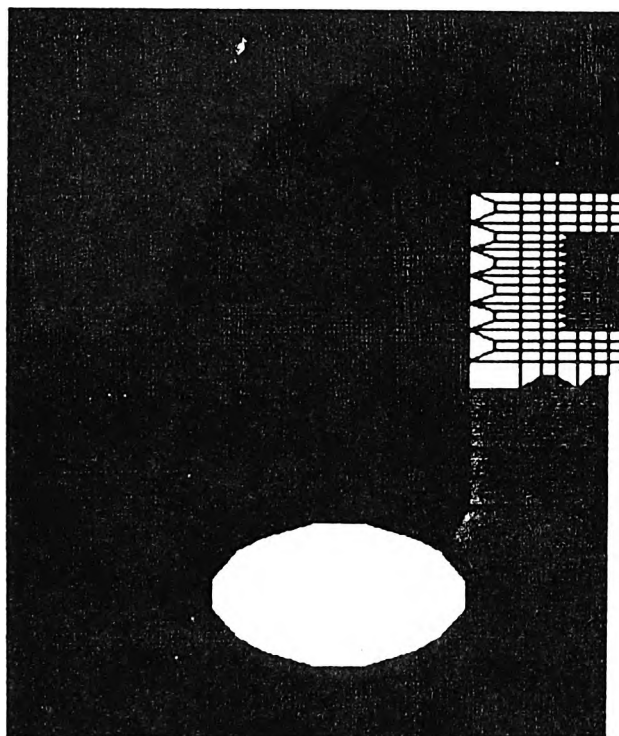
- o At high temp. T , atoms are at random positions (Disordered State) \Rightarrow High Energy.
Arbitrary allocation of elements to processors (Load Imbalance) \Rightarrow High Cost.
- o Cooling from $T \rightarrow 0$, allows atoms to migrate to an Ordered State of Low Energy. Degree of order depends on cooling rate:
Slow cooling (annealing) lower ground state than rapid cooling (quenching).

As initially assigned elements are allowed to migrate to processors (using monte carlo - based moves), The system becomes balanced.

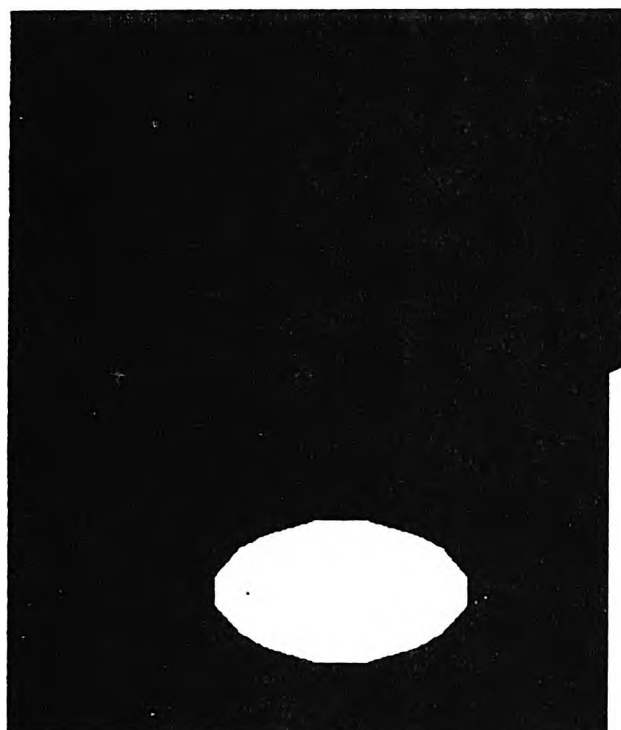


- ALGORITHM

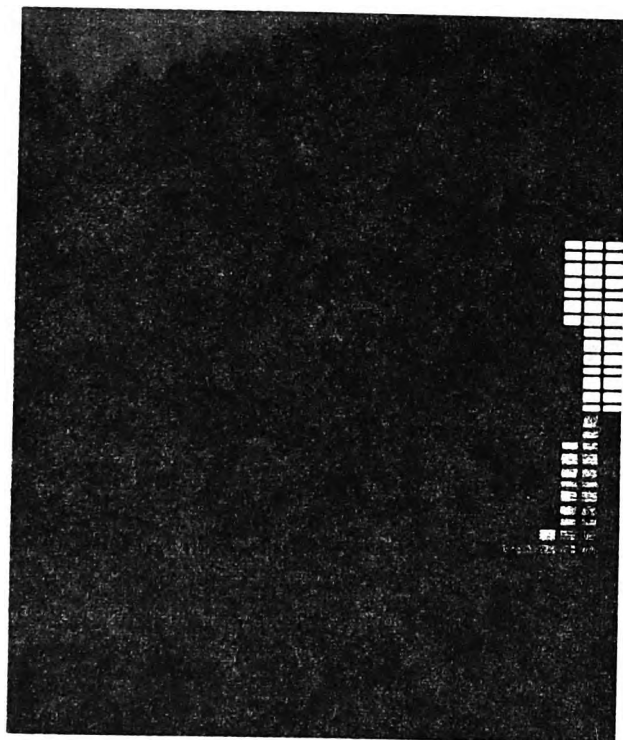




INITIAL ASSIGNMENT: WORKLOAD VARIATION 6 TO 331



ASSIGNMENT AFTER 20 CYCLES: WORKLOAD VARIATION 33 TO 35



DETAILS OF THE INTENSELY PACKED REGION

FUTURE PLAN

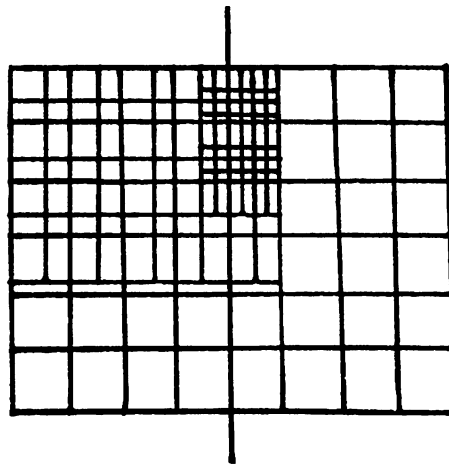
- **Load Balancing in MAX's Data Flow Environment**
 - o **Static load balancing: assignment of processes to processors is done prior to execution and never altered.**
 - o **Dynamic load balancing: assignment of processes to processors is done dynamically as execution progresses.**
- **Develop Other Heuristics**

Performance Critical Decisions in Parallel Scientific Computations

David M. Nicol

*Institute for Computer Applications
in Science and Engineering*

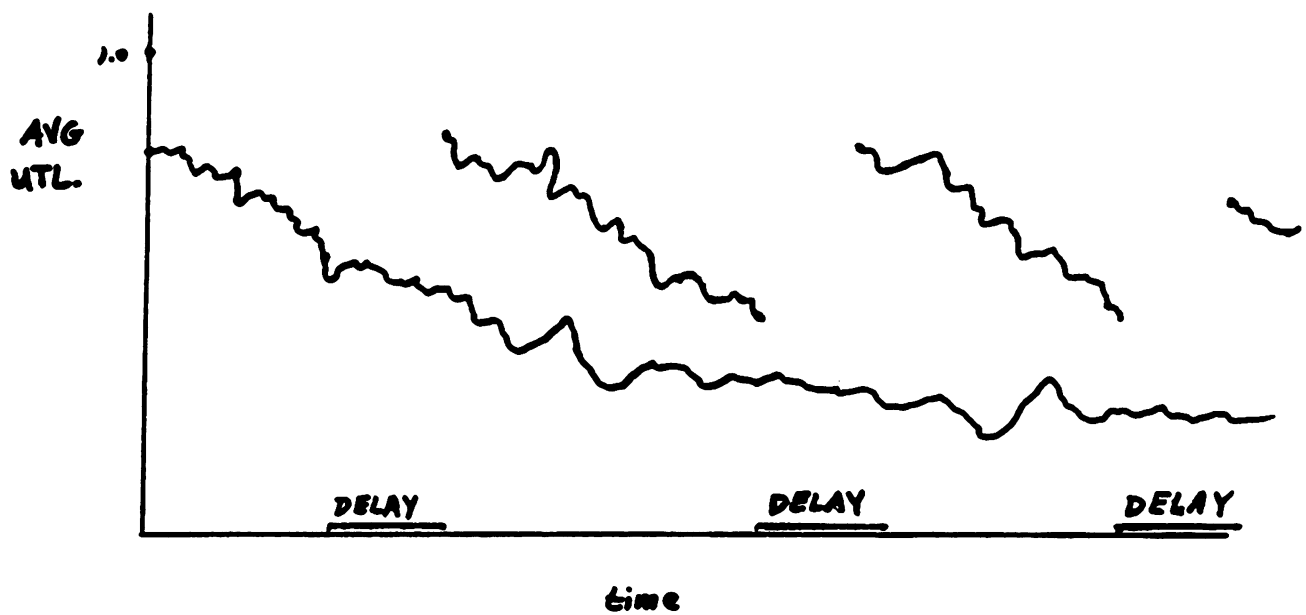
Mapping of parallel scientific computation to message passing architectures is usually domain oriented



- **Workload can change dynamically**
 - **When should we remap?**
- **Convergence testing performed every iteration**
 - **How can we avoid excessive overhead?**

Workload dynamics: continuous change

- e.g. Vortex methods for incompressible fluid flow



Optimal Remapping Decision Policy

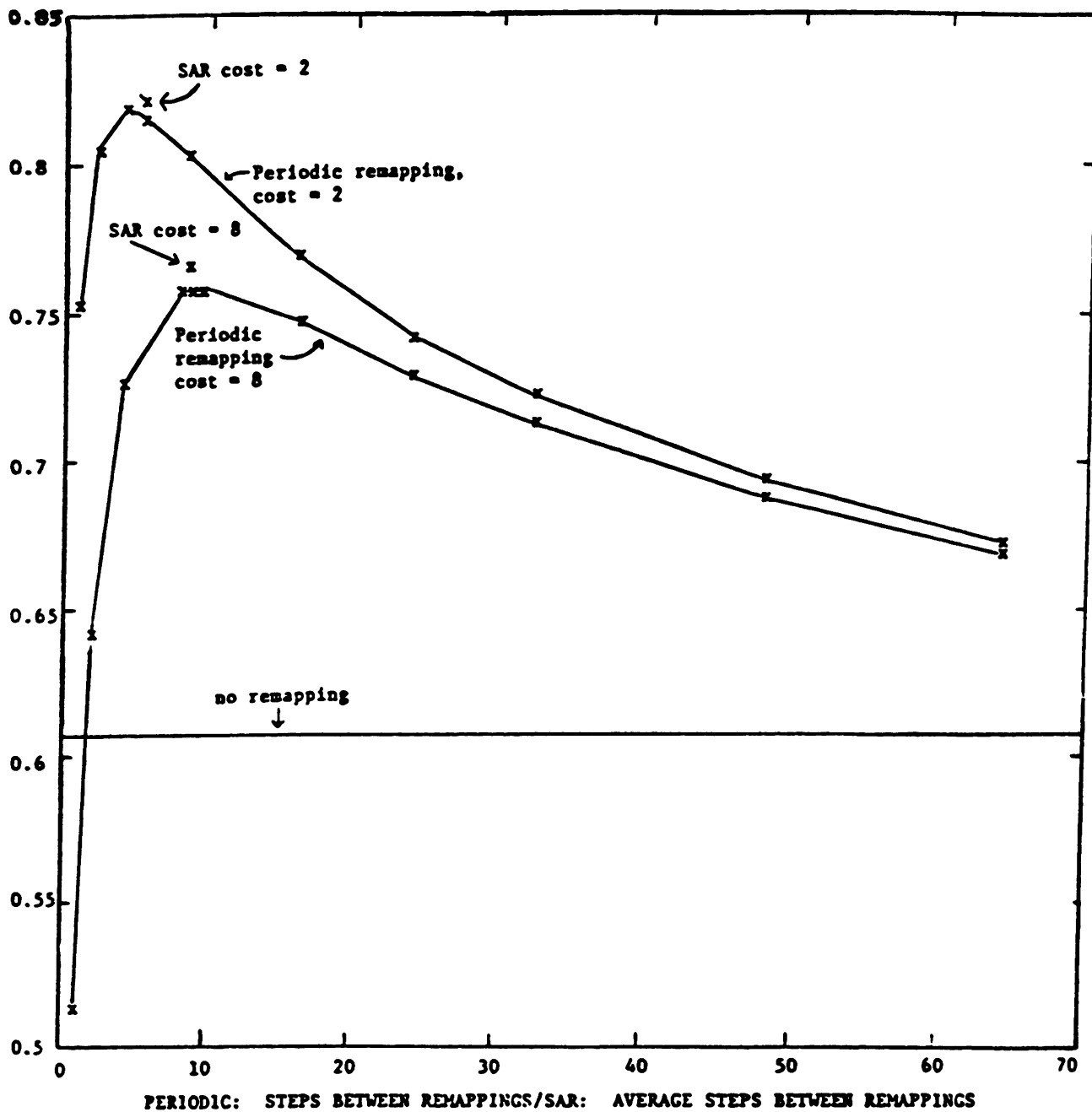
- Calculation of MDP possible with small model
- Optimal policy knows "too much" about system

Decision Heuristic

- Attempt to minimize average cost per step

$$W(n) = \frac{\sum_{i=1}^n (\max(i) - \text{avg}(i)) + C}{n}$$

- As function of n $E[W(n)]$ has at most one local minimum
- How to tell when $W(n)$ minimized?
 - Approximate with SAR

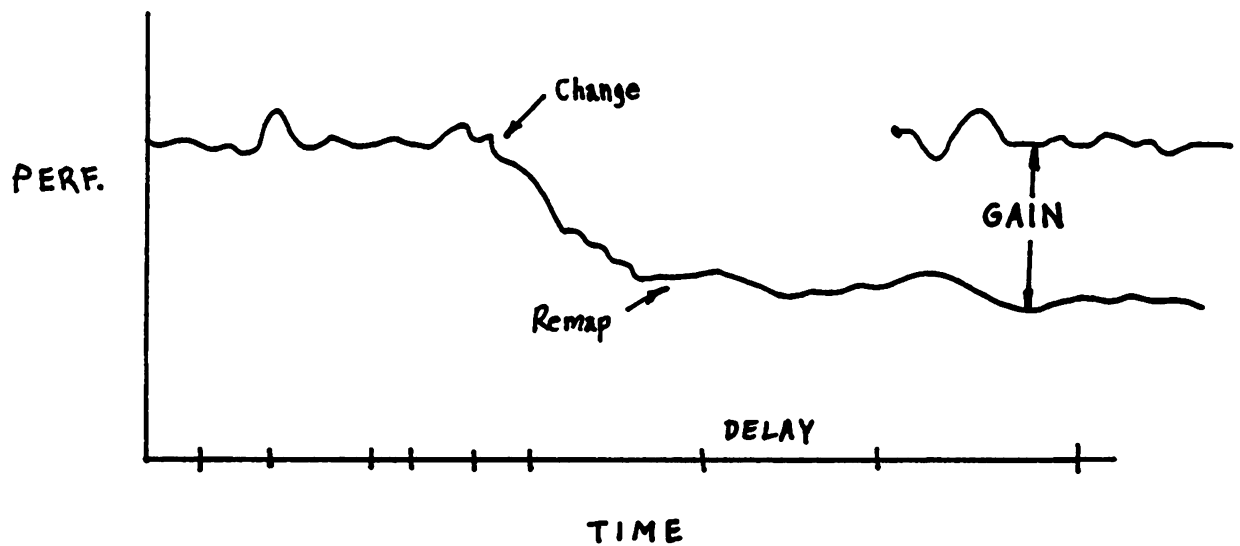


MUM Model: Performance of SAR Compared with Performance of Periodic Remapping.

Eight chains, 400 steps, each chain has 19 states, $p = 0.5$, each data point calculated from 200 sample paths.

Workload dynamics: abrupt change

- e.g. Multi-phase computations



Remapping Decision Heuristic

- Many decision model parameters difficult to estimate
- Examined fixed ρ -threshold policy
- $\rho \in [.7, .8]$ nearly optimal within envelope of admissible costs and gains
 - Difference from NR policy depends on gain
 - Keep ρ high to avoid unneeded overhead, low to avoid inaccurate test statistics
 - Policy tolerates mis-estimation of statistical parameters
- Conclusion: Remapping decision is manageable, focus on determining when gain is possible
 - *in envelope?*
 - *gain potential?*

Convergence Checking

- Goal is to reduce overhead by reducing number of checks
- Need to balance cost of check with threat of overshoot
- Choose iteration (offset) n to maximize average number of "useful" iterations

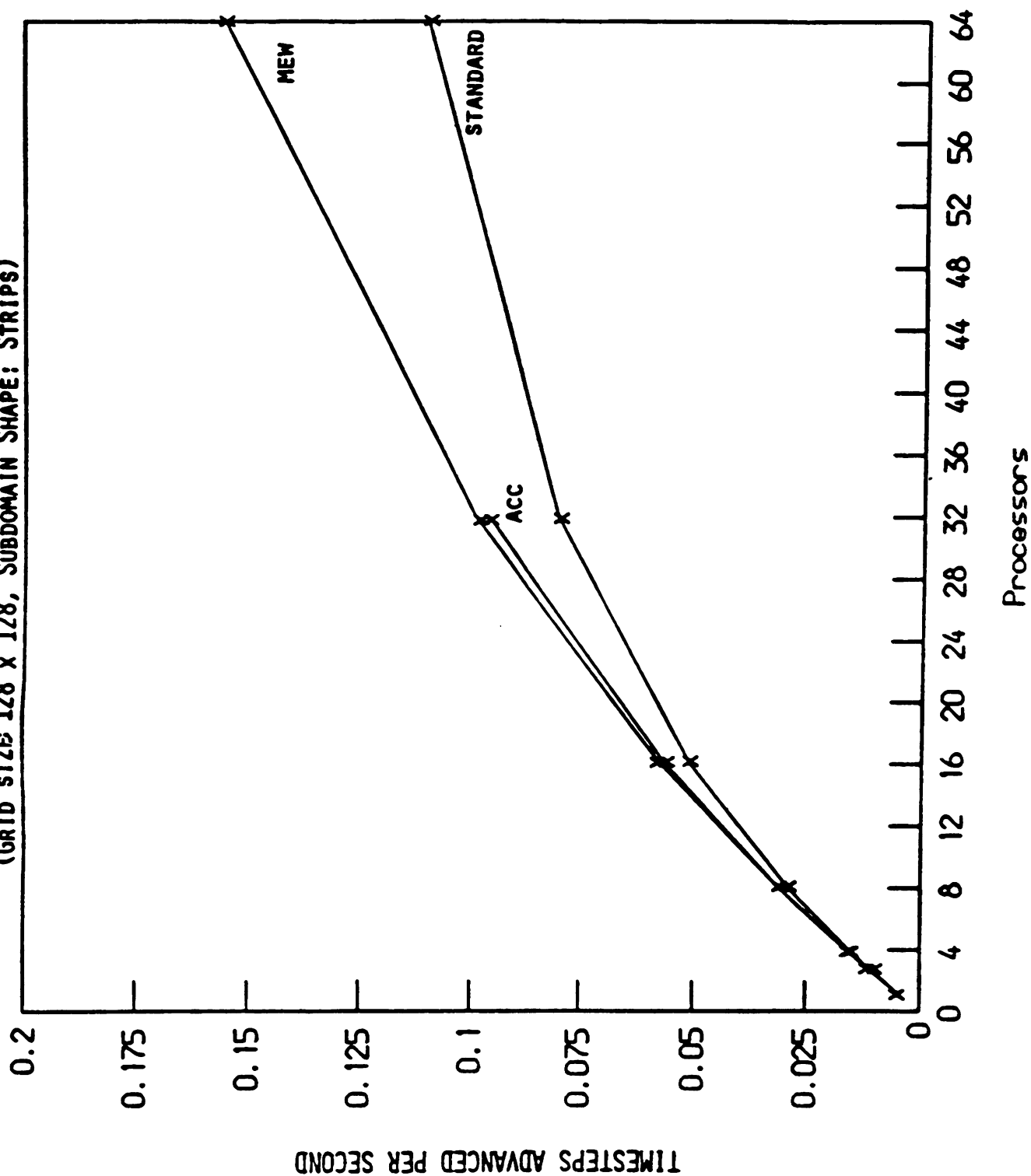
$$\frac{\sum_{i=1}^n \text{Prob}\{\text{Iteration } i \text{ is needed}\}}{n \cdot D + I}$$

— D iteration cost

— I cost of convergence check

- Probability terms computed using Bayesian techniques

EFFECT OF CONVERGENCE CHECKING SCHEMES ON ALGORITHM PERFORMANCE.
(GRID SIZE 128 x 128, SUBDOMAIN SHAPE: STRIPS)



Conclusions

- High performance in parallel scientific computations requires treatment of decision problems
 - Remapping decisions
 - Convergence checking decisions
- Simple "greedy" heuristics work nearly optimally
- Need to ensure that decision policies can be implemented at system level

Sparse Distributed Memory

M. Raugh/RIACS

This work entails:

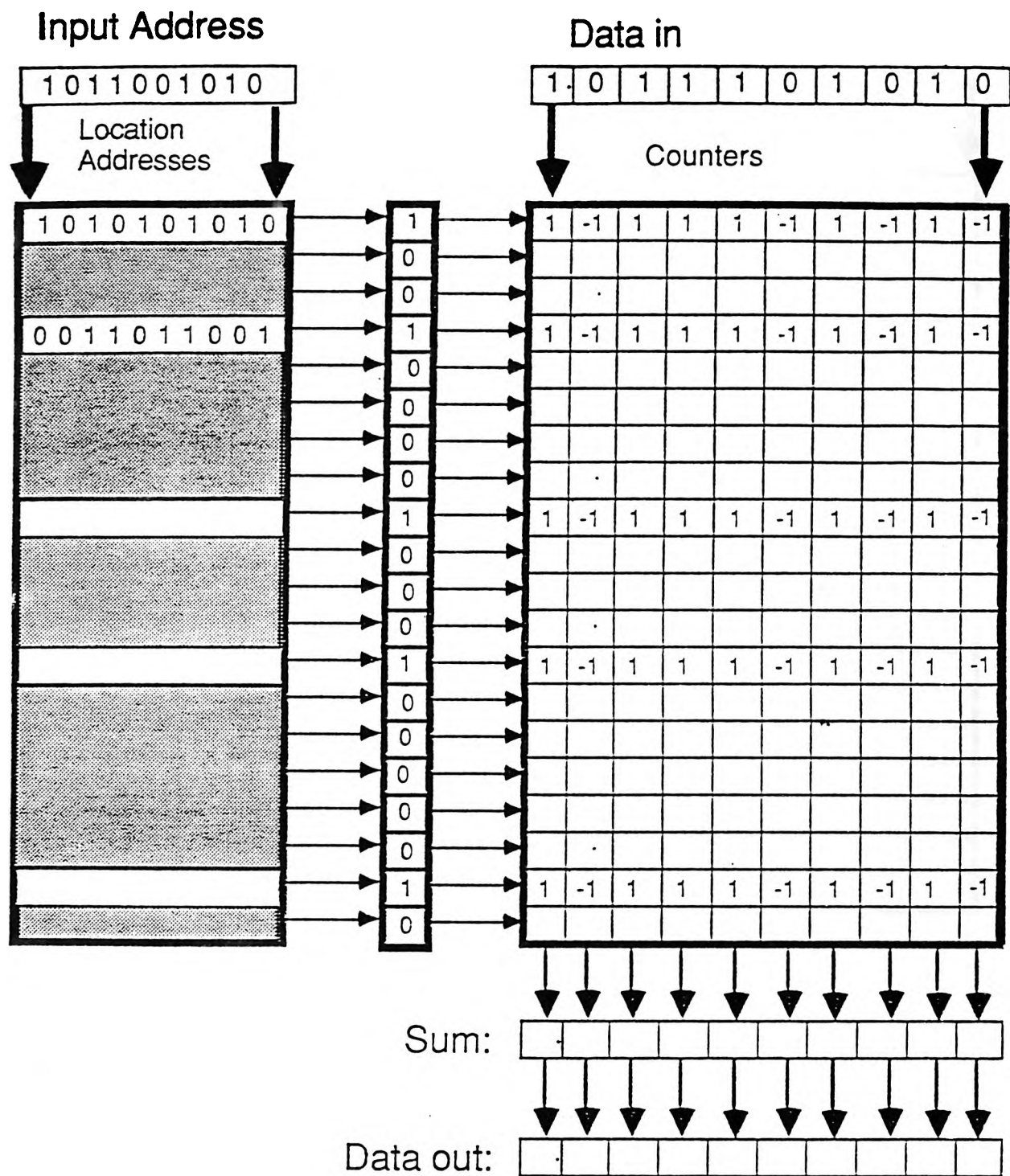
1. Programming a simulator of the proposed architecture on the Intel iPSC parallel computer or the Symbolics Lisp machine or both.
2. Developing simple models of an environment and of sensory input to and effector output from memory and use the simulator to study learning by trial and error in this simple environment.
3. Comparing the models developed in (b) to human and animal sensory and effector systems operating in the real world and prepare recommendations about further research.
4. Preparing recommendations about the building of special-purpose hardware for sparse, distributed memories and about the uses of such memories.
5. Relating findings of this research to facts about human memory and perception and prepare recommendations for the design of artificial environments for humans, with emphasis on environments where the cost of human error is very high.

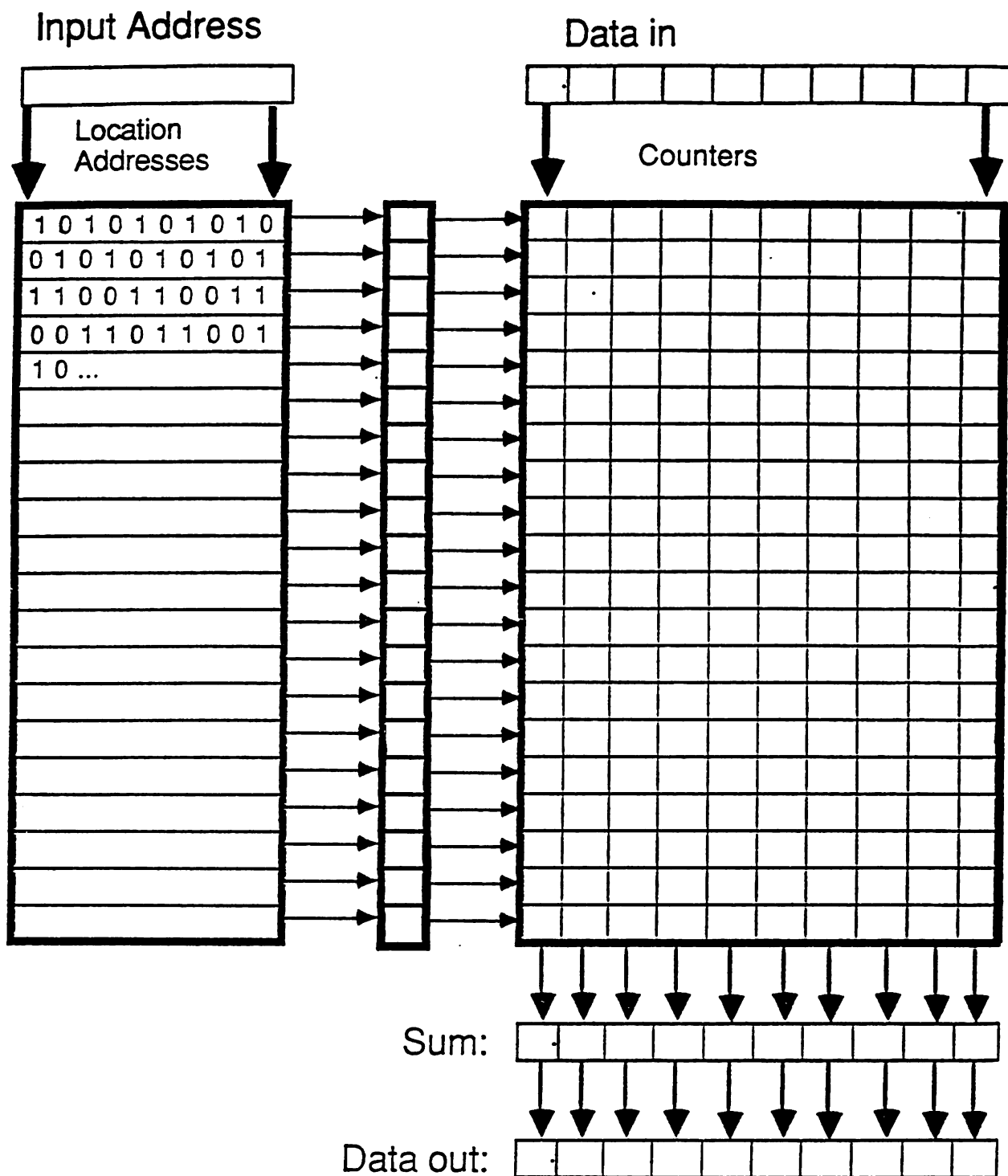
Scope of Task

- Feasibility study
 - Assess merits of SDM
 - Decide whether and how to build
 - SDMs for real tasks
 - Full-scale VLSI implementation
- A fundamental question
 - How to code the sensory inputs?
 - For research applications in
 - Robotics
 - Pattern recognition
 - Cognitive science
 - Interpretation of continuous speech

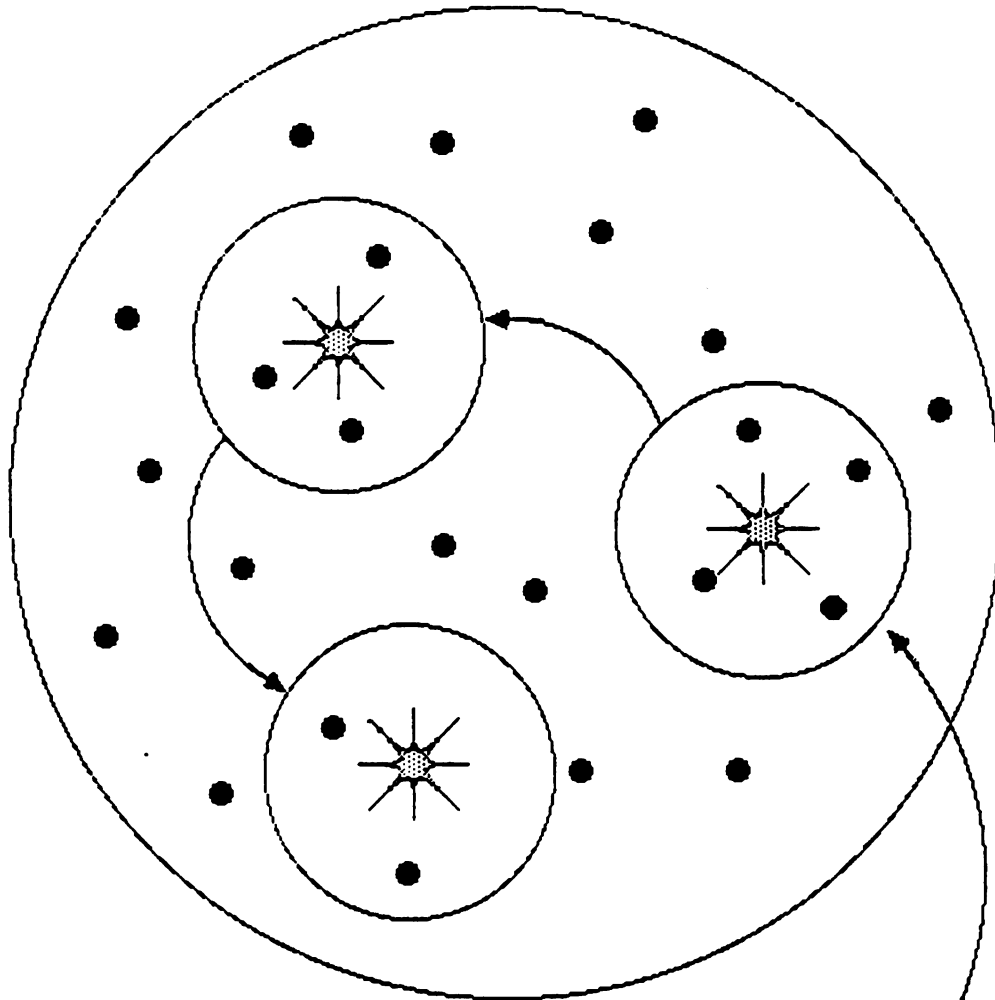
Theory Yields New Computer Architecture

- Distinction between memory and processing disappears
- Processing
 - Massively parallel
 - Distributed throughout memory
- 10–100 memory locations on a chip
- A computer based on the SDM





Items may be stored as a linked list



Head of list (initial item)



Main Properties of Model Memory

- Addresses can be chained (linked list)
 - Stream of recall
 - Causal relations
- SDM is sensitive to similarity
 - If you "know" 600 bits
 - And correctly "guess" 200 more
 - You will probably converge to correct memory
- SDM is capable of forgetting!
 - But can be reinforced by rehearsal

Another initial condition? (1=yes)

1 random (0) or perturbed initial condition(1)?

1 Which memory state to perturb around?

6 With what noise level? (0.0 to 1.0)

.2 The initial condition is:

```
XX XX XXXX XX
XX XX XXXXXXXXXXXX
XXXXX XXXXXXXXXXXXXX XXXX
XXX XXXXXXXXXXXXXX XX
XXX XXXX XXXXXXXXXX
XXXX XXXX XXXXXXXXXXXX
XXXX XX XXXXXX XX
XXXX XXXXXXX XXXX XX
XX XX XXX XXXXXXXX XX
XXXX XX XX
XXXXXXXXXX XX XXXXXX
XXXX XXXX XXXX XX XX
XX XX XXX XXXX XX
XXXXXXXXXX XXXXXXXX XX
XX XX
```

(initial condition)

type 1 'or' to continue

1 selected locations-11
XXXX

```
XXXX XXX XXXXXXXXXXXX
XXXX XXXXXX XXXXXXXXXXXX
XXXX XXXXXX XXXX XX
XXXX XXX XXXXXXX XXXX
XXXX XXX XXXXXXXXXXXX
XXXXXXXXXXXXXXXX XXXX
XXXX XXX XXXX XXXX
XXXX XXX XXXX XX
XXXX XXX XXXXXX XXXX
XXXX XXX XXX XXXX
XX XXX
```

Another iteration with this initial condition (1)?
1 selected locations-13

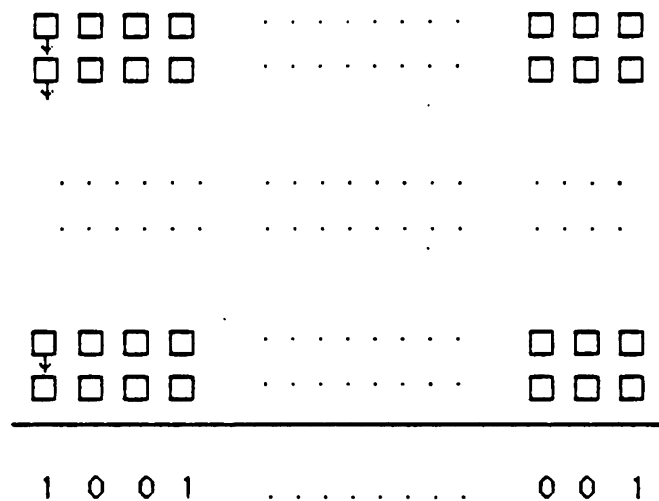
```
XXXX XXX XXXXXXXXXXXX
XXXX XXX XXXXXXXXXXXXXX
XXXX XXX XXX XXXX XXXX
XXXX XXX XXX XXXXXXXX
XXXXXXXXXXXXXXXX XXXX
XXXXXXXXXXXXXXXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
```

Another iteration with this initial condition (1)?
1 selected locations-14

```
XXXX XXX XXXXXXXXXXXX
XXXX XXX XXXXXXXXXXXXXX
XXXX XXX XXX XXXX XXXX
XXXX XXX XXX XXXX XXXX
XXXX XXX XXX XXXXXXXX
XXXXXXXXXXXXXXXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
XXXX XXX XXX XXXX
```

Reading is columnar addition:

Add corresponding counters from all selected locations



Each 0-bit results from a negative column-sum

Each 1-bit results from a positive column-sum

Writing:

Each physical memory location contains 1,000 counters

□ □ □ □ □ □ □

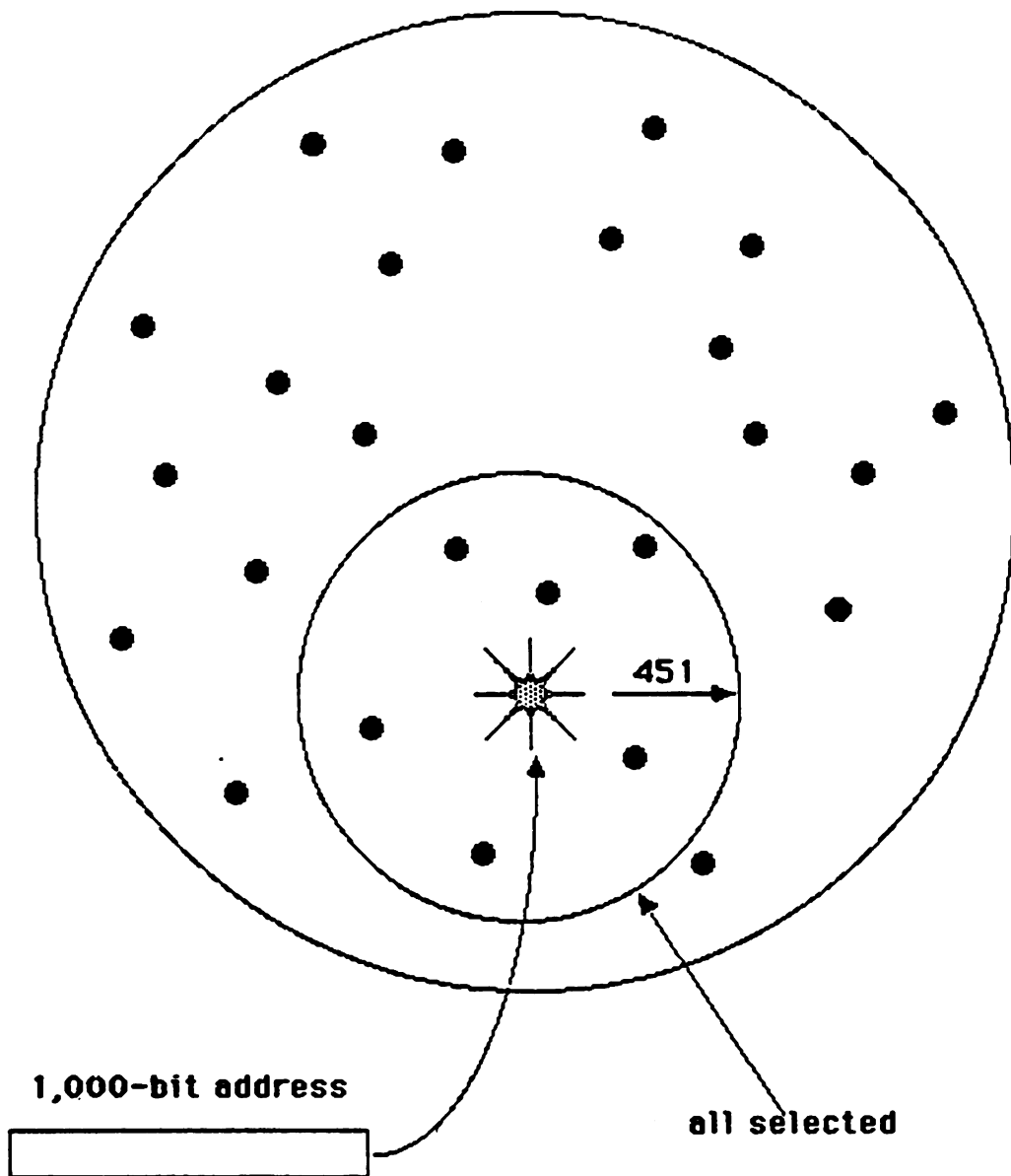
Each address contains 1,000 bits

1 0 0 1 0 0 1

Each 1-bit adds 1 to the corresponding counter

Each 0-bit subtracts 1 from the corresponding counter

Addressing

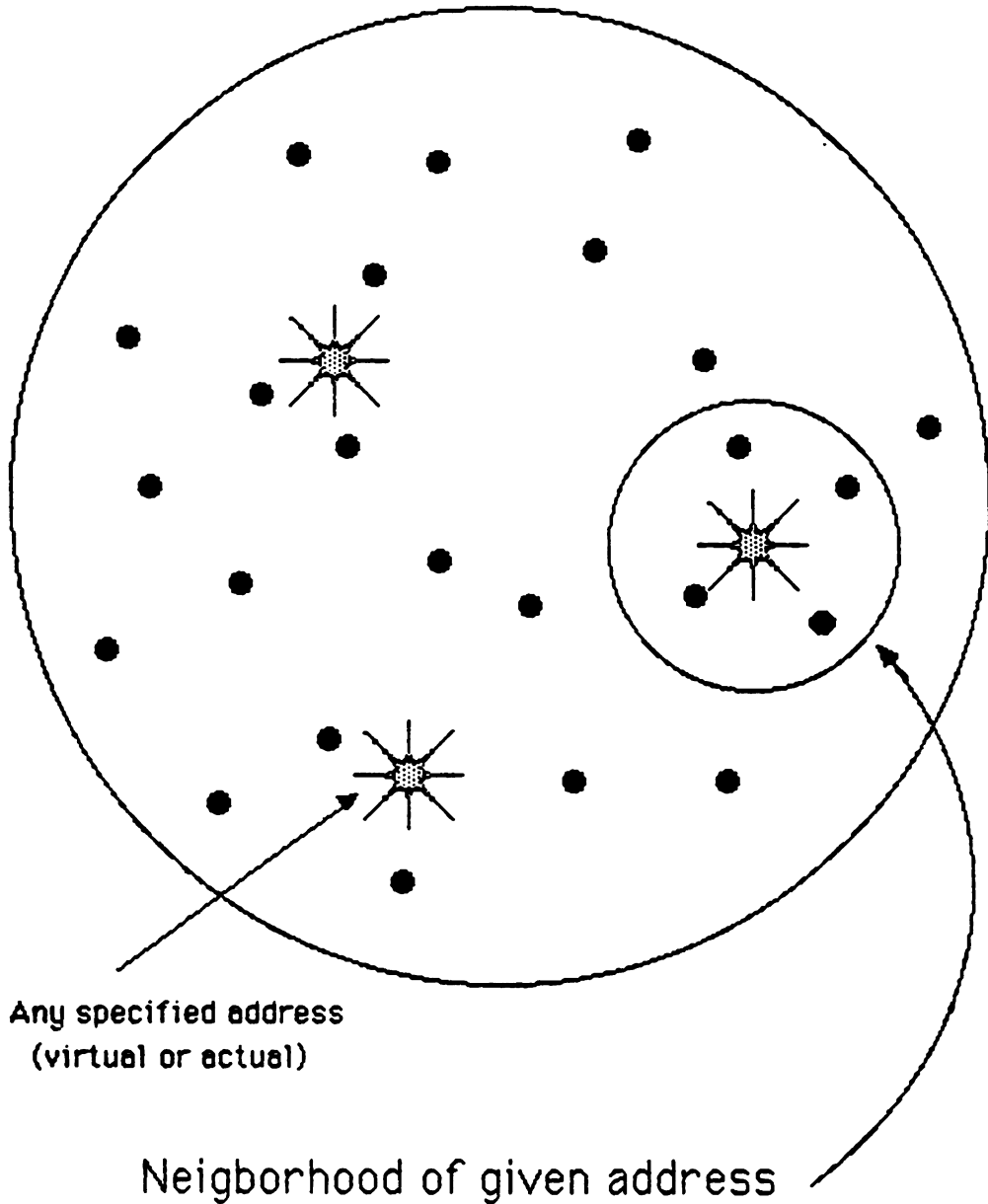


Gist of Theory (II)

- Sparse, *distributed* memory
- Reading and writing at specified address
- (Hamming distance between binary memory addresses)
 - Write to locations within radius of 451
 - Yields on average 1,000 physical locations
 - Read from locations within radius of 451

Huge Virtual Address Space

- Few actual memory locations

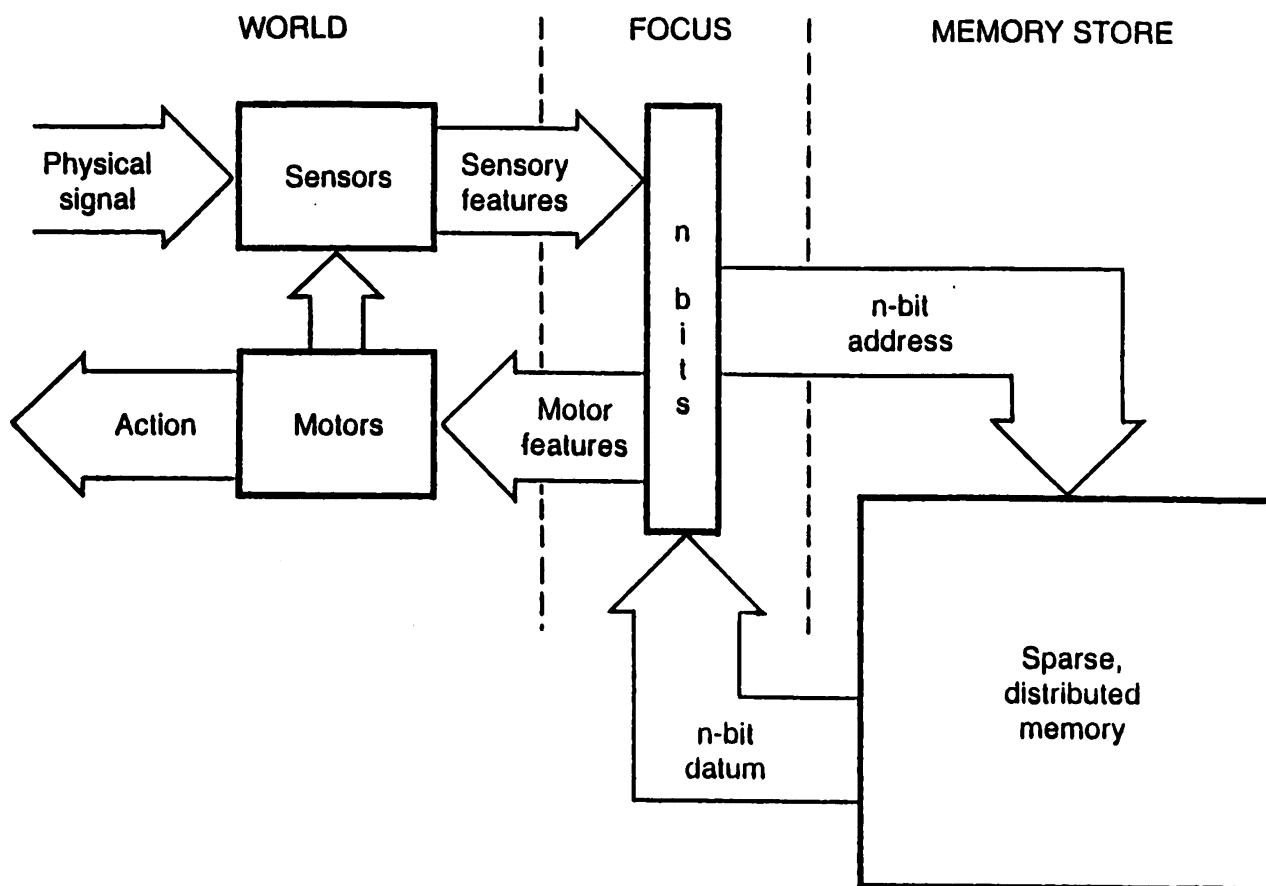


Gist of Theory (I)

- *sparse*, distributed memory
 - Huge (virtual) address space: 2^{1000}
 - Few (actual) physical memory locations: 2^{20}
 - Sprinkled randomly throughout the address space

Preliminary Assumption

- 1,000 bits code one moment of experience
 - Each coded moment serves as an address
- Kanerva postulates the existence of a *focus*
 - Clearing point for data going into or out of memory
- The coding problem is not addressed by Kanerva's existing theory
 - but will be addressed by this task



Sparse, Distributed Memory

- Massively parallel architecture
- Information stored in large number of neighboring addresses determined by "content"
- Memory is dynamic:
 - changes with experience
 - learns
 - causal relationships
 - time—varying phenomena
- Memory is sensitive to similarity
 - and it is
 - forgetful !!!
 - (but can be reinforced)

Kanerva's Theory of Sparse, Distributed Memory (SDM)

- A model of human memory
 - Explicit
 - Simple
 - Engineerable
- Dissertation being published by Bradford Books of MIT Press

PROJECT: SPARSE DISTRIBUTED MEMORY

CHARACTERISTICS:

- Highly-parallel pattern computer
- Based on Kanerva's mathematical theory of human memory

PARTICIPANTS:

- Pentti Kanerva (RIACS), Project Manager
- Harrison Leong (RIACS)
- David Nagel (Ames)
- Michael Flynn (Stanford)

STATUS:

- Completed simulators
- Building digital prototype

DISTRIBUTED OPERATING SYSTEMS

FACT OR FANTASY?

ED FOUDEIAT

NASA-LARC

- DOS/DS COME IN MANY FLAVORS
- ADDRESS LAN WITH MID TO HIGH COMMUNICATIONS $\approx 10^7$ B/S

SHARED MEMORY	VS	NON SHARED MEMORY
PARALLEL	VS	DISTRIBUTED
ADDRESS OR FETCH/STORE	VS	MESSAGE OR SEND/RECEIVE
COMMUNICATIONS UNDER O/S	VS	COMMUNICATIONS IN O/S

DOS LIKE PARALLEL SUPPORTS DISTRIBUTED
PROCESSING, DATA, & CONTROL

QUESTION - UNDER WHAT CONDITIONS IS
EACH APPLICABLE ?

A CASE FOR SHARED MEMORY

MESSAGE STEPS:

1. APPL. PROCESS PREPARE

INFO - CALL SEND

2. SEND PROCESS - PREPARE

HEADER & CONTROL - SEND

3. RECEIVE MESSAGE - HANDLE

CONTROL - LOCATE RECIPIENT

4. RECIPIENT PROCESSING.

OPERATIONAL STEPS:

- 1 CONTEXT SWITCH
- 2 COPY
- 3 LOCATE - ROUTINE OPS
- 4 COMM. PROTOCOL OPS - SEQ, FLOW
5. PHYSICAL TRANSMISSION
- 6 HANDLE RECEIVE INTERRUPT
- 7 SET COMMUNICATION STATE
- 8 LOCATE RECIPIENT
- 9 COPY
- 10 CONTEXT SWITCH

SUPPOSE EACH STEP .1 - 1.0 MSEC

SUPPOSE RECEIVE STEPS TO 3-5

MESSAGES MINIMUM 1 MSEC - 10 MSEC.

OBSERVATIONS

CPU OPERATIONS ARE LIMITING FACTOR

COMM. IMPROVEMENTS - 10^{-10}
CPU " " - 10

BEST MESSAGE SYSTEMS .5 MSEC.

SUPPORT:

EO GERINGER - N.C. STATE ENG. CE DEPT.

CH * MESSAGE SYSTEM 14X SLOWER

PARALLEL MACHINES USE FEW/STORE

CONCLUSION

FOR LAN WITH MID COMMUNICATIONS RATES:

- ALL BASIC COMM. ESTABLISHED BACKPLANE TO BACKPLANE IN HARDWARE
- SERIAL CPU ACTIVITY IN COMM. NOT PRACTICAL
- NONSHARED MEMORY DOS FOR AUTONOMOUS AND/OR LOW COMM RATE ENVIRONMENTS - NOS
- ASYNCHRONOUS MESSAGE AS BASIC (LOW LEVEL) DOS PARADIGM NOT PRACTICAL

HIGH PERFORMANCE BASED DOS IS A FANTASY.
WHEN PERFORMANCE COUNTS DON'T SEND MESSAGES.

PARALLEL / SHARED MEMORY SYSTEMS

- CROSSBAR AND OTHER SWITCHED MEMORY
- PARTITIONED - LOCAL CACHE WITH CONTROLS
- SEPARATED MEMORY BLOCKS
- NEIGHBORHOOD CONNECTIVITY CUBES, MESSENGERS, ETC

BASIC PROBLEMS

NAMING THAT'S HARDWARE COMPATIBLE

CONSISTENCY UNDER PARALLEL OPS

MAINTAINING CORRELATION OVER OPERATION
(LATENCY)

MAINTAINING OPERATIONS UNDER
FAILURE

TWO BASIC MEMORY OPERATIONS

• FETCH/STORE

ASYNCHRONOUS OR

HARDWARE RESOLVED

DUPLICATE/"MULTIPLY" INFORMATION

SHORT TIME FRAME OR

• SEND/RECEIVE (MESSAGE) CONNECT (VIRTUAL CIRCUIT)

SYNCHRONOUS OR

HARDWARE RESOLVE. CPU CONTROLLED

DUPLICATE/"MULTIPLY" INFORMATION

LONG TIME FRAME OR

NOTE: FULL DUPLEX VIRTUAL CIRCUIT SATISFIES SEQUENCING AND FAILURE REQUIREMENTS. OTHER DISTRIBUTED/PARALLEL PROBLEMS HAVE HIGH COMMUNALITY

CONCLUDING REMARKS

- HIGH PERFORMANCE DISTRIBUTED AND PARALLEL COMPUTING SYSTEMS ARE LOGICAL EQUIVALENTS

SOT, SPACE STATION, ADVANCED EMBEDDED WILL

USE SHARED MEMORY

- DIST. "SHARED MEMORY" HARDWARE CONCEPTS NEED IDENTIFICATION & SELECTION

- A COMBINED FETCH/STORE, COMBINED MACHINE STATE NEED
- RESEARCH ON MESSAGE PROTOCOL OPERATIONS, ETC., CAREFULLY

REQUIRED

- CLOSER ALLIANCE BETWEEN DISTRIBUTED & ANALOG RESEARCH ACTIVITIES -- LOTS OF COMMONALITY

SPACE & EARTH
SCIENCES
DIRECTORATE

DIRECTORATE

CODE 600

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE (DAVID) SYSTEM



HETEROGENEOUS DISTRIBUTED DATABASE MANAGEMENT-- THE DAVID SYSTEM

Barry E. Jacobs
Senior Research Scientist
NASA/GSFC

NOV. 19, 1986

DR0058 A-2

SPACE & EARTH
SCIENCES

DIRECTORATE

CODE 600

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE (DAVID) SYSTEM



PROBLEM:

NASA SCIENTISTS AND MANAGERS HAVE TO LEARN
MANY DIFFERENT ACCESS METHODS IN ORDER TO
OBTAIN DATA.

<u>DEVICES</u>	<u>OPERSYS</u>	<u>DBMSS</u>	<u>COMMUNICATIONS</u>	<u>NASA DATA SYSTEMS</u>
IBM	DOS	IMS	ARPA NET	NASA OCEAN DATA SYSTEM (NODS)
VAX	UNIX (BSD)	DB2	DEC NET	NASA LAND DATA SYSTEM (NLDS)
CDC	UNIX (AT&T)	ORACLE	BIT NET	TECHNICAL MANAGEMENT
SUN	VMS	INGRES	DIAL-UP	INFORMATION SYSTEM (TIMIS)
CRAY	IBM OS	SEED	IBM NET	NASA ASTROPHYSICS DATA
		CODASYL		SYSTEM (NADS)

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE (DAVID) SYSTEM



SOLUTION:

DISTRIBUTED ACCESS VIEW INTEGRATED
DATABASE (DAVID) SYSTEM

<u>DEVICES</u>	<u>OPER SYS</u>	<u>DBMS</u>	<u>COMMUNICATIONS</u>	<u>NASA DATA SYSTEMS</u>
IBM VAX CDC SUN CRAY	DOS UNIX (BSD) UNIX (AT&T) VMS IBM OS	IMS DB2 ORACLE INGRES SEED CODASYL	ARPA NET DEC NET BIT NET DIAL-UP IBM NET	NASA OCEAN DATA SYSTEM (NODS) NASA LAND DATA SYSTEM (NLDS) TECHNICAL MANAGEMENT INFORMATION SYSTEM (TMIS) NASA ASTROPHYSICS DATA SYSTEM (NADS)

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE (DAVID) SYSTEM



OUTLINE OF TALK

- WHAT IS DAVID?
- USER'S VIEW OF DAVID
- DEMONSTRATION SYSTEM
- ASTROPHYSICS DATA SYSTEM
- HOW DAVID WORKS

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE (DAVID) SYSTEM



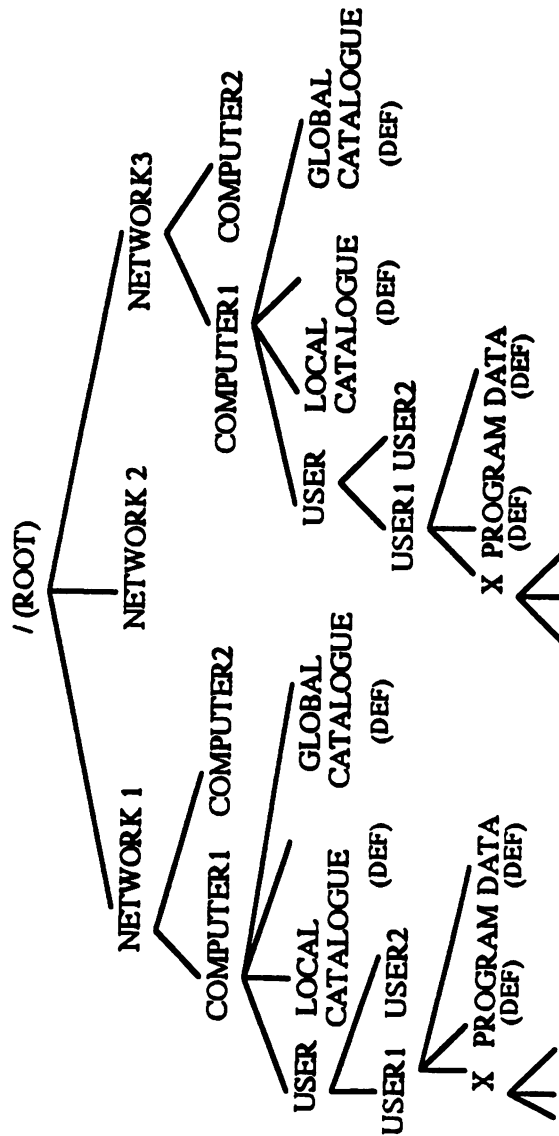
WHAT IS DAVID?

- DAVID IS A SYSTEM FOR ACCESSING HETEROGENEOUS DISTRIBUTED DATABASES.
- DAVID IS A STANDALONE HOMOGENEOUS DISTRIBUTED DATABASE MANAGEMENT SYSTEM.
- DAVID IS A HETEROGENEOUS DISTRIBUTED OPERATING SYSTEM.
- DAVID IS A HETEROGENEOUS COMMUNICATIONS SYSTEM.

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE (DAVID) SYSTEM



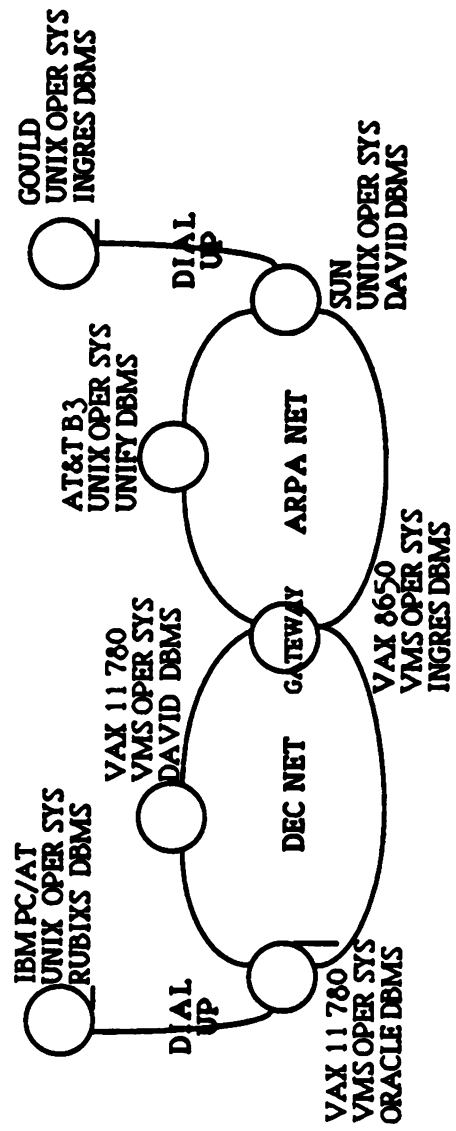
USER'S VIEW OF DAVID



DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE (DAVID) SYSTEM



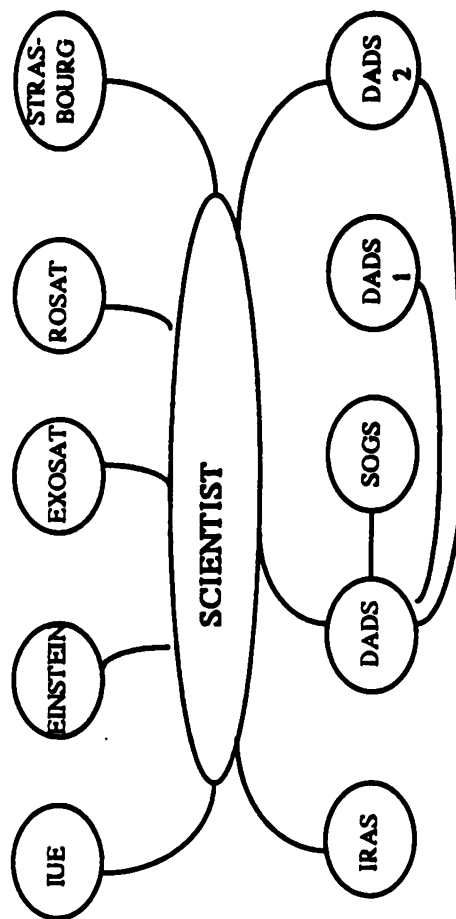
PHASE I: DEMONSTRATION SUBSYSTEM



**DISTRIBUTED ACCESS VIEW INTEGRATED
DATABASE (DAVID) SYSTEM**



PHASE II. THE ASTROPHYSICS DATA SYSTEM



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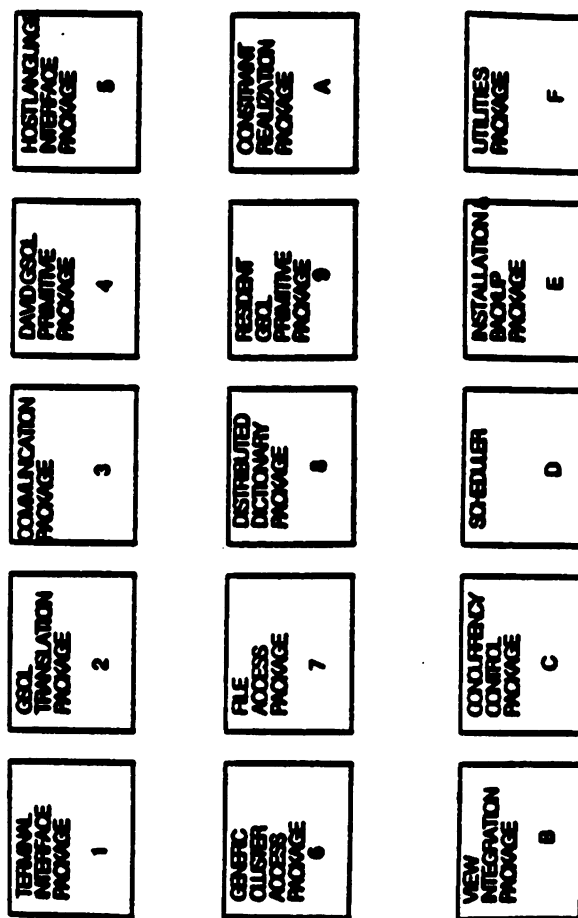
CODE 600

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE (DAVID) SYSTEM



DAVIDTM DBMS

SYSTEM OVERVIEW



<p>NASA</p>		<p>NATIONAL SPACE SCIENCE DATA CENTER</p>
	<p>INTELLIGENT DATA MANAGEMENT PROCESSES</p>	

NOVEMBER 19, 1986

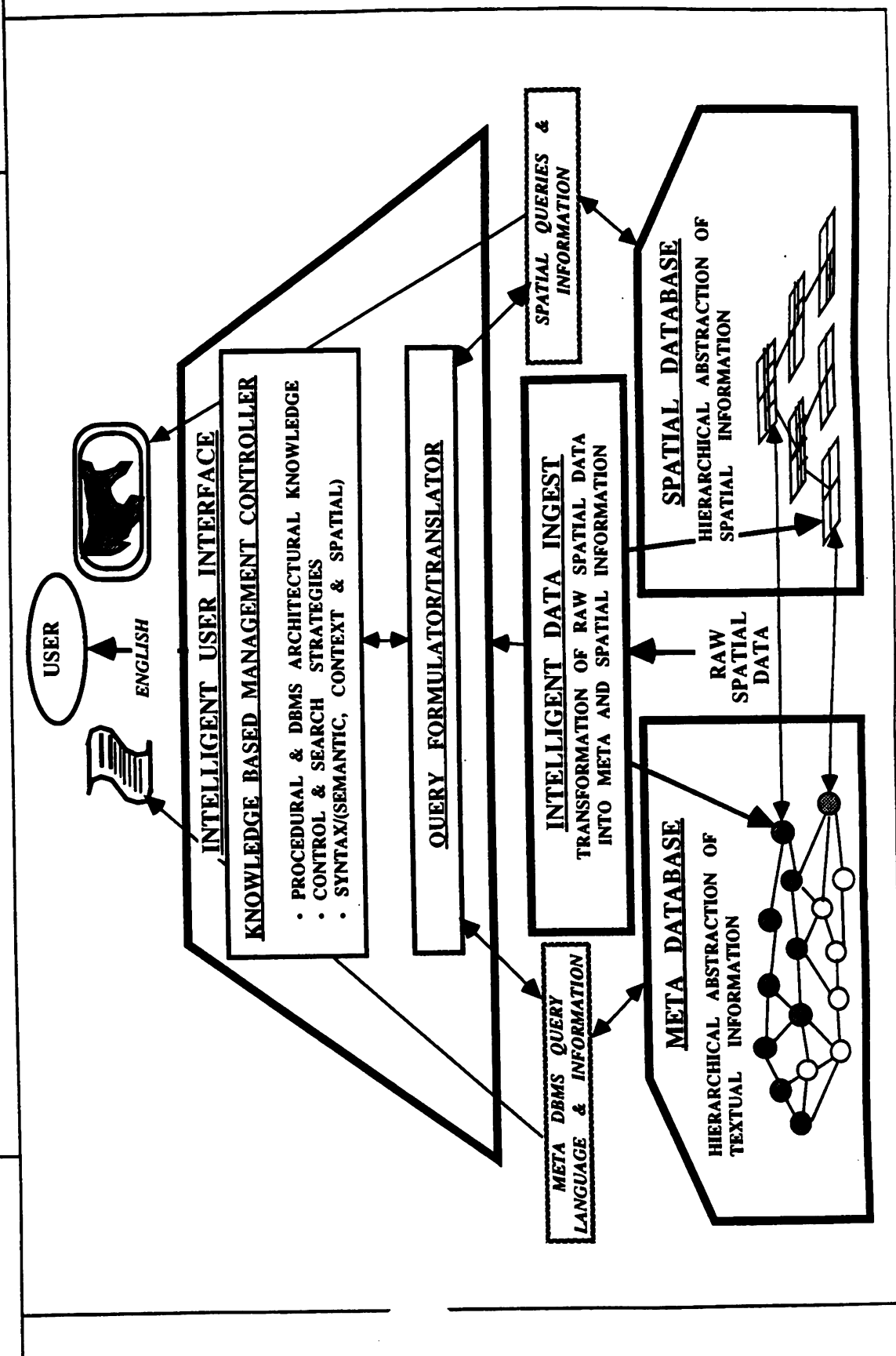
W. J. CAMPBELL

**IT IS POSSIBLE TO DEVELOP ADVANCED DATA
MANAGEMENT SYSTEMS AND SERVICES THAT WILL
FUNCTION LIKE A COLLECTIVE GROUP OF KNOWLEDGE-
ABLE DATABASE EXPERTS AND SUPPORT ENGINEERS
SUCH THAT THE SYSTEM CAN SUPPORT A WIDE RANGE
OF USERS THAT HAVE MINIMAL DATABASE
UNDERSTANDING AND EXPERIENCE**

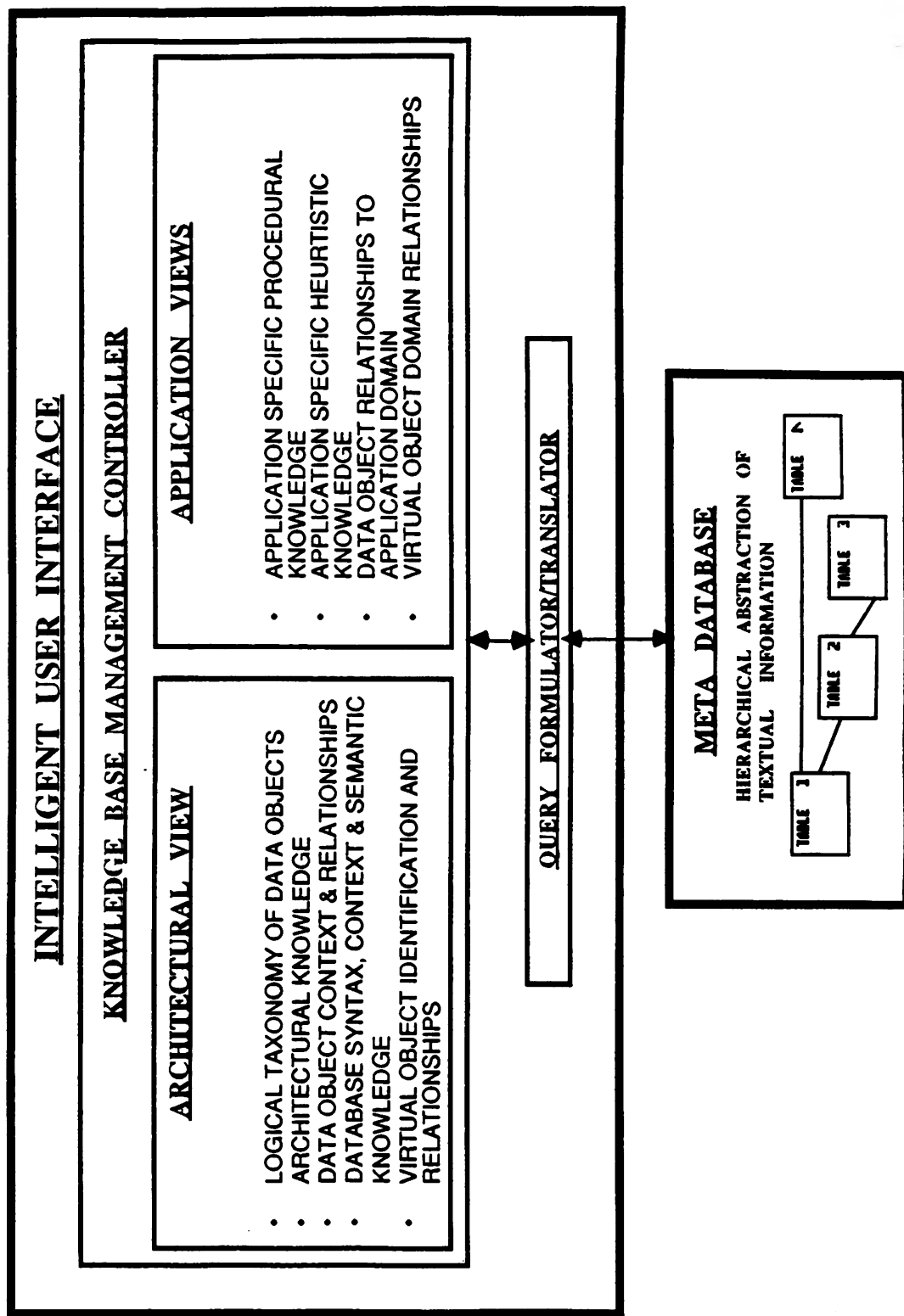
NASA	BASIS FOR THE HYPOTHESIS	NATIONAL SPACE SCIENCE DATA CENTER
	<ul style="list-style-type: none"> • A DATABASE HAS A FINITE AND RATHER LIMITED KNOWLEDGE SPACE WHICH MAKES THE APPLICATION OF EXPERT SYSTEMS AND RELATED AI TECHNOLOGIES POSSIBLE • MANY OPERATIONS THAT ARE PERFORMED BY EXPERT DATABASE USERS ARE BASED ON HEURISTIC OR PROCEDURAL KNOWLEDGE • ALTHOUGH MOST OPERATIONAL DATABASES CAN HAVE A LARGE NUMBER OF DATA OBJECTS, THE ACTUAL NUMBER OF USEFUL OBJECTS IS USUALLY RATHER LIMITED, AND FOR ANY SPECIFIC APPLICATION DOMAIN IS SMALL • EXPERT SYSTEMS WILL ALLOW THE IMPLEMENTATION OF MULTIPLE DATABASE VIEWS AND SUPPORTING SEARCH STRATEGIES FOR A BROAD RANGE OF DOMAIN SPECIFIC APPLICATIONS 	

IDM CONCEPT

NASA



OVERVIEW OF INTELLIGENT USER INTERFACE DESIGN

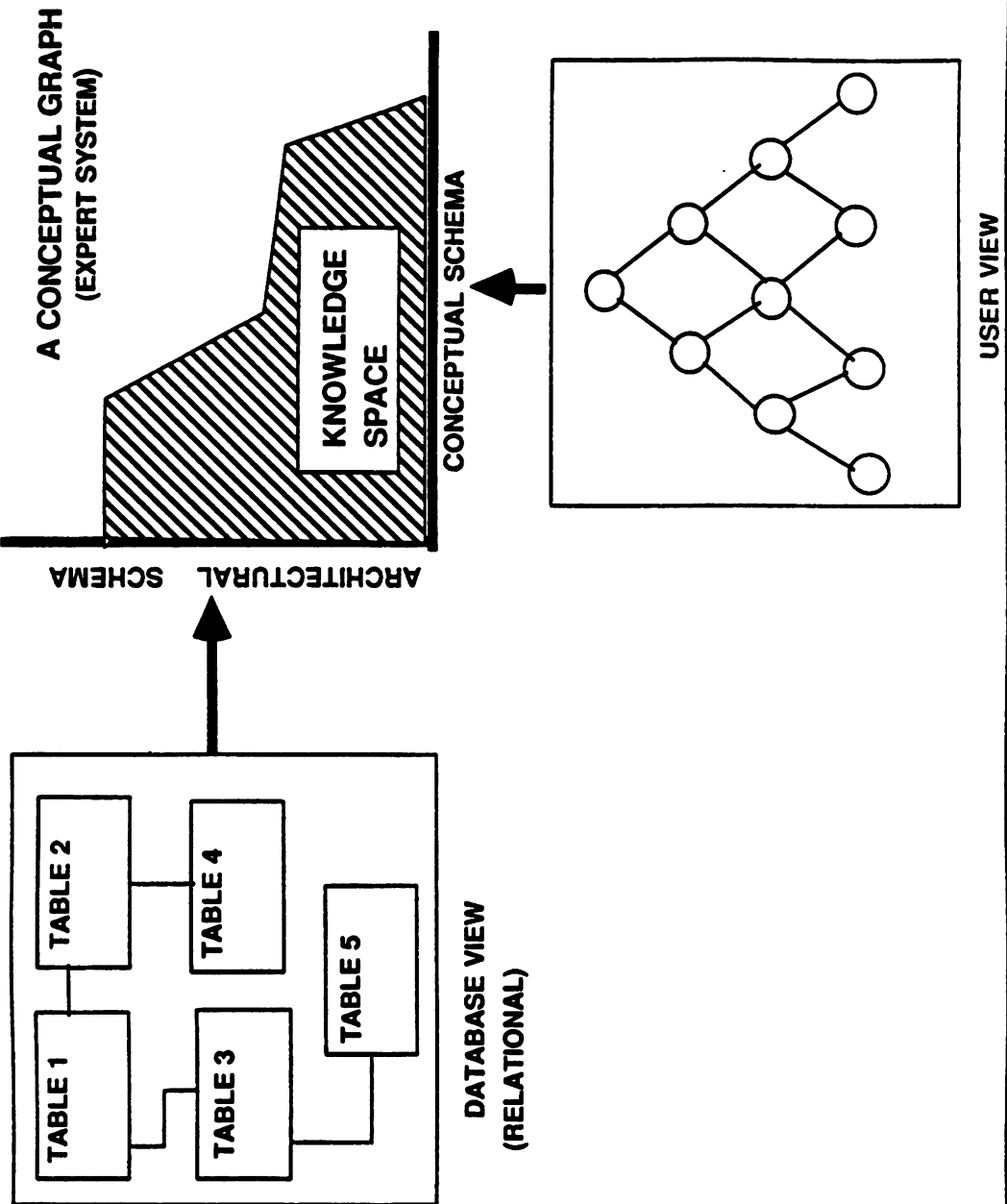


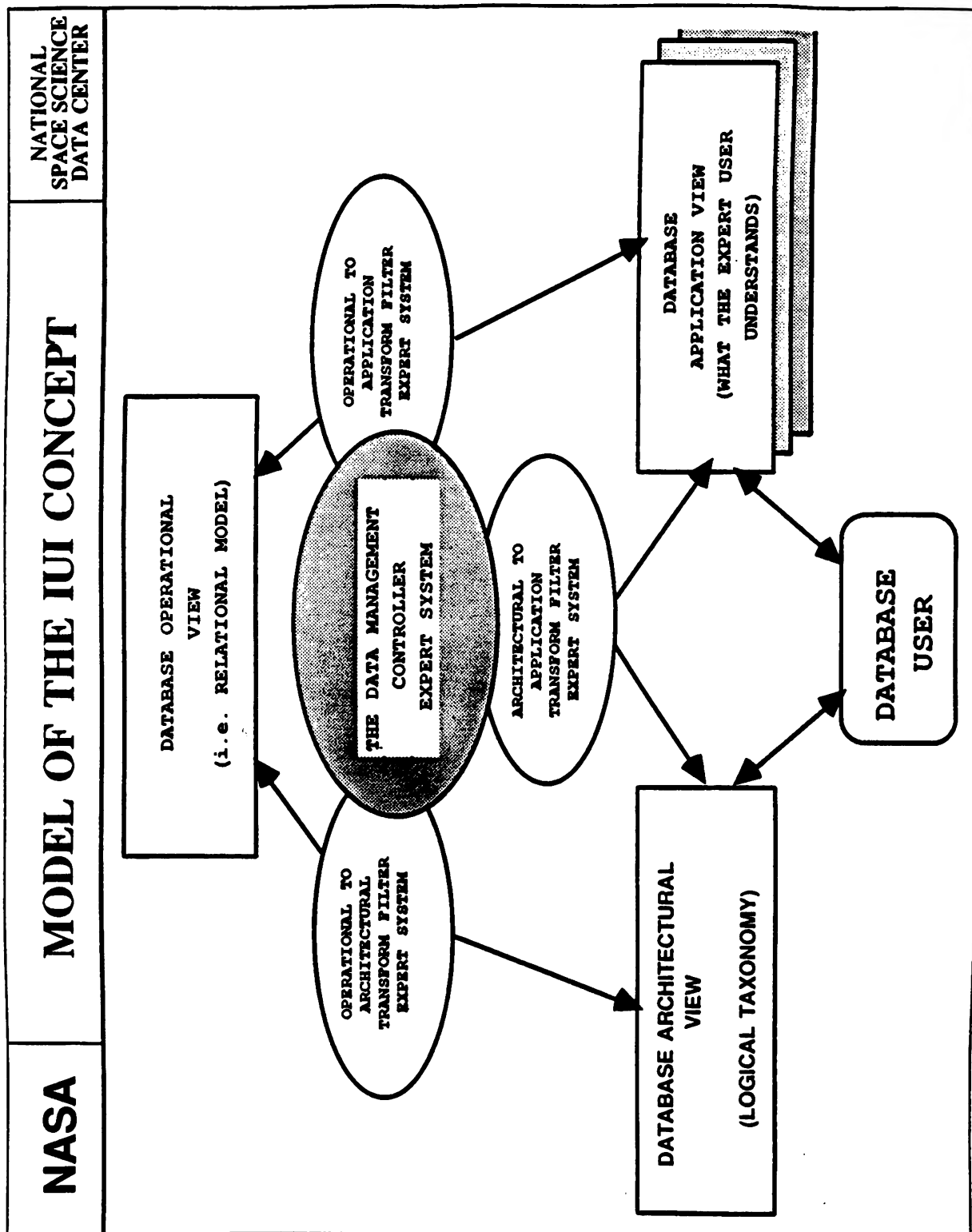
NASA	EXPECTED IUI CAPABILITIES	NATIONAL SPACE SCIENCE DATA CENTER
	<ul style="list-style-type: none"> • IT CAN FACILITATE UNDERSTANDING BY SPECIFYING THE CONTENTS AND MEANINGS OF A COLLECTION OF DATA AS WELL AS THE RELATION BETWEEN OBJECTS WITHIN THE DATA • IT CAN SUPPORT APPROXIMATE REASONING BY INFERRING CONCLUSIONS THAT ARE NOT EXPLICITLY STATED BY THE USER, SUCH AS AN IMPRECISE QUERY • FUZZY CONCEPTS CAN BE EXPRESSED BY USING A FUZZY QUERY • IT CAN HANDLE INFORMATION DEMAND FOR WHICH THE DATABASE IS USED ROUTINELY, RAPIDLY AND EFFICIENTLY WITHOUT ANY UNDERSTANDING BY THE USER • CAN COMMUNICATE WITH THE USER IN PLAIN ENGLISH TEXT 	

NASA	EXPECTED IUI CAPABILITIES (CONTINUED)	NATIONAL SPACE SCIENCE DATA CENTER
	<ul style="list-style-type: none"> <li data-bbox="528 462 659 1518">• CAN SERVE AS THE SEMANTIC BASIS FOR UNDERSTANDING THE USER'S DATA NEEDS IN CONJUNCTION WITH THE NATURAL LANGUAGE QUERY PROCESSOR <li data-bbox="705 462 836 1518">• CAN PROVIDE A LOGICAL REPRESENTATION OF THE DATABASE ARCHITECTURE AND INFORMATION STORED IN THE DATABASE TO THE CASUAL USER <li data-bbox="882 462 1059 1518">• CAN FACILITATE AN UNDERSTANDING AND IDENTIFICATION OF DATABASE INFORMATION FROM THE DATABASE OPERATIONAL VIEW TO THE USER RELATED VIEWS BY USING CONCEPTUAL GRAPHS 	

NASA	IUIS DESIGN CONCEPTS	NATIONAL SPACE SCIENCE DATA CENTER
	<ul style="list-style-type: none"> • REPRESENT THE META DATABASE BY VIEWS THAT ARE FUNCTIONALLY APPROPRIATE TO THE USER AND AT THE SAME TIME OPERATIONALLY NECESSARY TO REPRESENT THE ACTUAL DATABASE • CREATE TWO GENERAL TYPES OF VIEWS OF THE META DATABASE: <ul style="list-style-type: none"> - AN ARCHITECTURAL VIEW - MULTIPLE APPLICATION VIEWS • DEVELOP PROCESSES BASED ON CONCEPTUAL GRAPHS THAT WILL ALLOW LOGICAL TRANSLATION BETWEEN THE VARIOUS DATABASE VIEWS 	

NASA	IUI DESIGN APPROACH	NATIONAL SPACE SCIENCE DATA CENTER
	<ul style="list-style-type: none"> • USE EXPERT SYSTEMS TO SUPPORT THE DEVELOPMENT OF THE INTELLIGENT USER INTERFACE • REPRESENT THE APPLICATION VIEWS WITH GOAL DIRECTED BACKWARD CHAINING PROCESSES THAT CAPTURES EXPERT HEURISTIC AND PROCEDURAL KNOWLEDGE • REPRESENT THE ARCHITECTURAL VIEW USING A FRAME BASED CONCEPT THAT WILL SUPPORT OBJECT ORIENTED RELATIONSHIPS AND INHERITANCE • USE CONCEPTUAL GRAPHS TO TRANSLATE BETWEEN THE DATABASE'S MEANING AND THE USER'S MEANING OF DATA OBJECTS AND SETS OF DATA OBJECTS • PROVIDE A LOGICAL LINK BETWEEN INFORMATION CONTAINED IN THE VIEWS OF THE META DATABASE AS WELL AS BETWEEN THE META AND THE SPATIAL DATABASE USING CONCEPTUAL GRAPHS 	



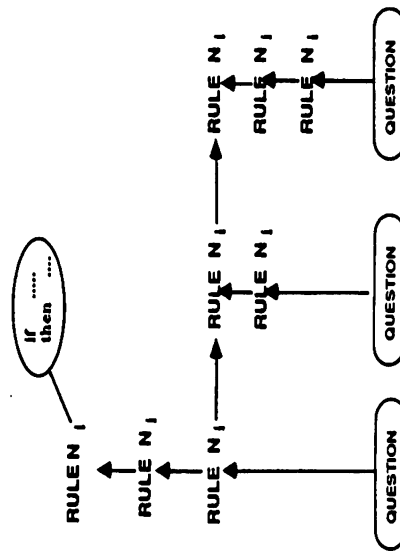
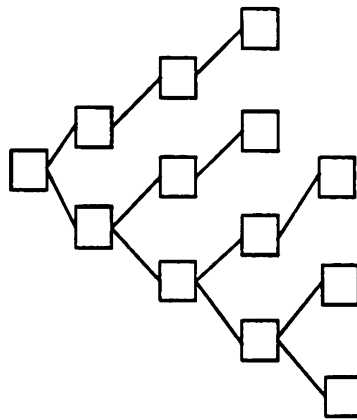


NASA	VIRTUAL OBJECTS	NATIONAL SPACE SCIENCE DATA CENTER
	<p>THERE IS A CLASS OF DATABASE OBJECTS THAT THE EXPERT USER KNOWS ABOUT BUT THAT DOES NOT EXIST IN THE DATABASE CALLED VIRTUAL OBJECTS (SOMETIMES CALLED INFERED OBJECTS)</p> <p>VIRTUAL OBJECTS ARE THE RESULT OF THE CLUSTERING OF SEVERAL TOUPLES (REAL DATABASE OBJECTS) TO FORM A NEW OBJECT</p> <p>PRESENTLY, VIRTUAL OBJECTS CAN ONLY BE IDENTIFIED AND MANAGED WITH A KNOWLEDGE BASE</p> <p>VIRTUAL OBJECTS ARE BEST REPRESENTED IN THE ARCHITECTURAL VIEW OF THE DATABASE, HOWEVER, THEY ARE MOST CERTAINLY USED IN THE APPLICATION VIEWS</p> <p>THE IMPORTANCE OF VIRTUAL OBJECTS CAN NOT BE OVER EMPHASISED BECAUSE THEY REPRESENT INFORMATION THAT THE DATA CONTAINS THAT DOES NOT EXIST EXPLICITLY IN THE DATABASE BUT IS THE RESULT OF AN EXPERTS KNOWLEDGE ABOUT THE DATABASE</p>	

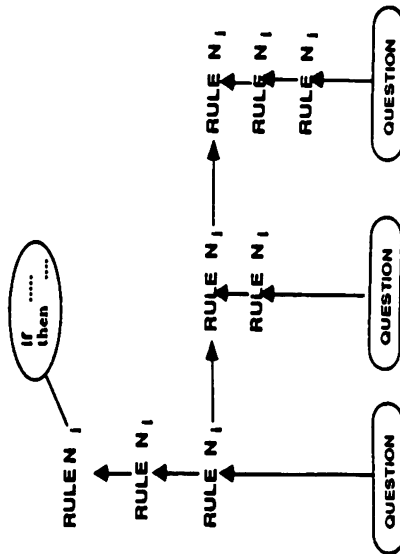
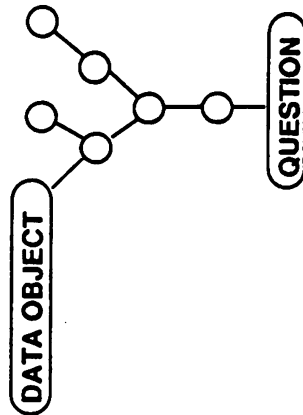
- FORMULATE, DESIGN AND PROTOTYPE PHASE ONE INTELLIGENT USER INTERFACE WITH THE FOLLOWING COMPONENTS:
 - KNOWLEDGE BASED MANAGEMENT CONTROLLER
 - QUERY FORMULATOR/TRANSLATOR
- PROTOTYPE INITIAL KNOWLEDGE BASED MANAGEMENT CONTROLLER USING EXPERT SYSTEM TECHNOLOGIES
- DESIGN, PROTOTYPE AND INTERFACED A QUERY FORMULATOR/TRANSLATOR TO THE KNOWLEDGE BASED MANAGEMENT CONTROLLER
- DEMONSTRATE THE PROTOTYPE SYSTEM WITH OPERATIONAL SCIENTIFIC DATABASE (CRUSTAL DYNAMICS PROJECT)

- TWO DATABASE VIEWS REPRESENTED: ARCHITECTURAL & APPLICATION
- ARCHITECTURAL VIEW BASED ON A MODIFIED HIERARCHY REPRESENTATION WITH LIMITED CONTEXTUAL INFORMATION
- SINGLE APPLICATION VIEW
- BOTH KNOWLEDGE BASE AND DOMAIN FACTS CONTAINED IN RULES AND SUPPORTING TABLES
- REASONING LIMITED TO GOAL DIRECTED BACKWARD CHAINING
- SINGLE LINE OF REASONING
- PROTOTYPE LIMITED BY EXPERT SYSTEM AND QUERY PROCESSING TOOLS AND COMPUTER RESOURCES

DATABASE ARCHITECTURE REPRESENTED IN
A LOGICAL HIERARCHY SUPPORTED BY MINIMUM
RELATIONSHIP BETWEEN DATA OBJECTS



APPLICATION VIEW IS RULE
BASED GOAL DRIVEN



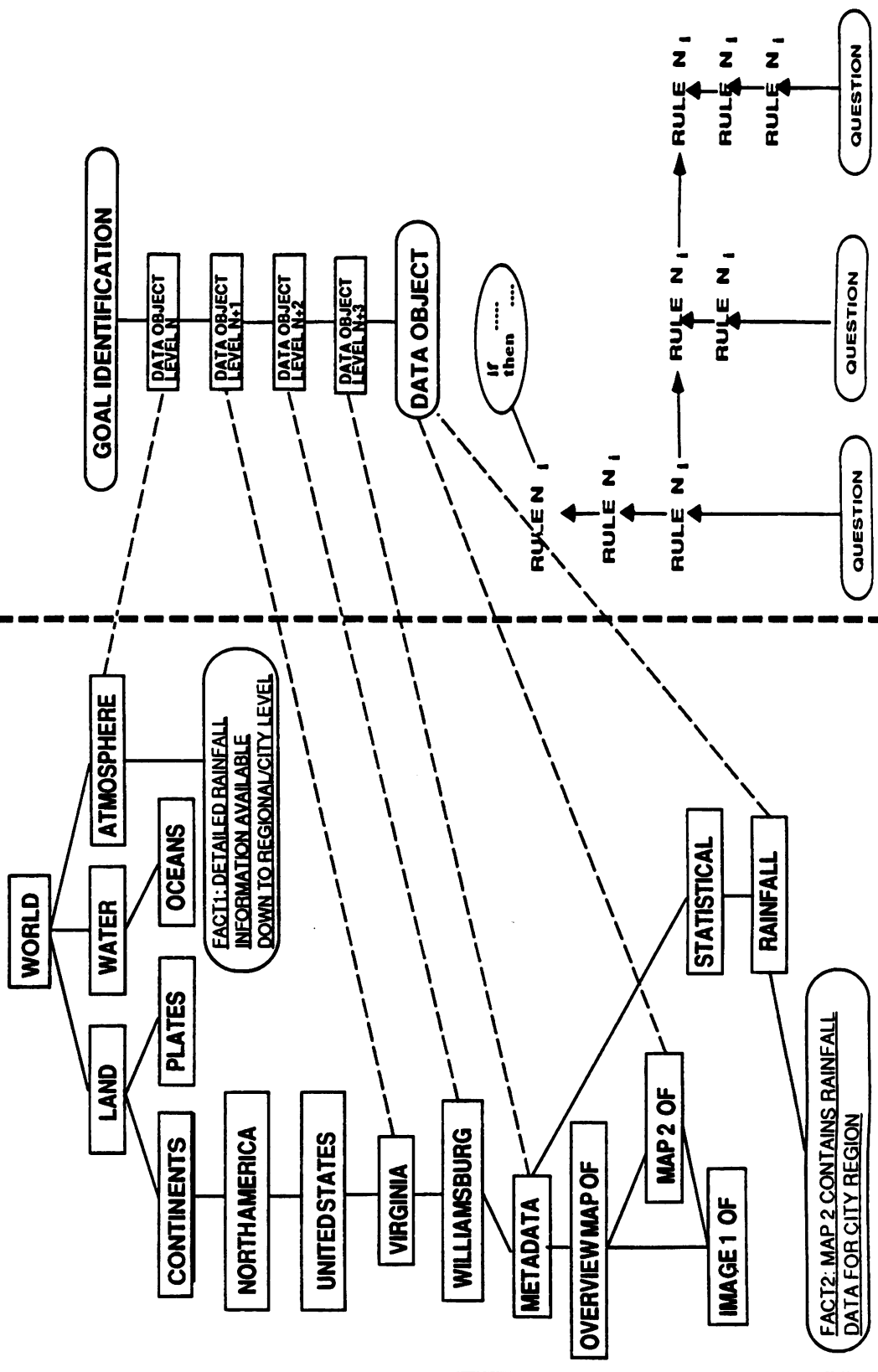
NASA	RESEARCH RESULTS	NATIONAL SPACE SCIENCE DATA CENTER
	<ul style="list-style-type: none"> • IT IS NECESSARY TO REPRESENT THE DATABASE WITH MULTIPLE VIEWS INCLUDING BOTH A LOGICAL AND OPERATIONAL VIEWS • IT IS POSSIBLE TO CREATE THE DATABASE VIEWS USING AN EXPERT SYSTEM • EXPERT SYSTEMS PROVIDE A MEANS OF REPRESENTING BOTH THE OPERATIONAL CONTEXT AND SEMANTICS TO A DATABASE AS WELL AS ITS SYNTAX • IT IS BETTER TO REASON IN THE EXPERT SYSTEM IN THE LANGUAGE DOMAIN OF THE USER • THE USE OF CONCEPTUAL GRAPHS ALLOW THE TRANSLATION BETWEEN THE VARIOUS DATABASE VIEWS • ENGLISH IS A VERY SYNTACTICALLY COMPACT LANGUAGE FOR REASONING ABOUT DATABASES • THE SYSTEM MUST INCLUDE VIRTUAL OBJECTS WHICH ARE THE RESULT OF THE CLUSTERING OF REAL DATABASE OBJECTS 	

- THE DEVELOPMENT OF AN ADVANCED KNOWLEDGE BASED MANAGEMENT CONTROLLER THAT SUPPORTS:
 - DATABASE ARCHITECTURAL VIEW BASED ON A LOGICAL TAXONOMY USING A FRAME BASED REPRESENTATION SCHEMA
 - THE IDENTIFICATION OF DATA OBJECT CONTEXT IN ARCHITECTURAL VIEW UTILIZING PARENT/DAUGHTER RELATIONSHIP INHERENT IN THE FRAME BASED DATA STRUCTURE
- INCLUSION OF GRAPHICAL DATA OBJECTS IN FRAME SCHEMA TO SUPPORT MANAGEMENT AND UNDERSTANDING OF HIGH LEVEL DATA OBJECTS (E.G., MAPS, DIAGRAMS)
- DEVELOPMENT OF A GENERALIZED QUESTION GENERATOR USING CONTEXT AND GOAL INFERED INFORMATION
- PROTOTYPE A SECOND GENERATION INTELLIGENT USER INTERFACE FOR AN OPERATIONAL SCIENTIFIC DATABASE

- MULTIPLE ARCHITECTURAL AND APPLICATION VIEWS REPRESENTED
- ARCHITECTURAL VIEW IS A HIERARCHICAL REPRESENTATION OF THE DATABASE OBJECTS WITH FULL CONTEXT RELATIONSHIP SUPPORTED BY FRAME BASED DATA STRUCTURE WITH INHERITANCE
- APPLICATION VIEW DOMAIN IS A SUBSET OF FULL ARCHITECTURAL VIEW DOMAIN WITH APPLICATION SPECIFIC RULE BASE
- DATA OBJECT SEARCH SUPPORTED BY CONCURRENT FORWARD AND BACKWARD REASONING
- PSUEDO PARALLEL DATA OBJECT IDENTIFICATION AND SELECTION (CONCURRENT MULTIPLE LINES OF REASONING) SUPPORTED BY MULTI-WORLD OPERATIONS
- DATA STRUCTURE SUPPORTS BOTH META AND SPATIAL DATA OBJECTS
- NEAR REAL-TIME CONSTRUCTION OF OPTIMAL SEARCH NETWORK USING PATTERN RECOGNITION PROCESSES THAT SUPPORT A DYNAMIC DATABASE ARCHITECTURE FOR APPLICATION SPECIFIC PROBLEMS

DESIGN OVERVIEW OF ADVANCED KNOWLEDGE BASE MGMT CONTROLLER

APPLICATION VIEW (GOAL DIRECTED)

LOGICAL TAXONOMY OF DATABASE OBJECTS
IN FRAME REPRESENTATION SCHEMA

PERFORMANCE COMPARISONS

INITIAL	ADVANCED
<div>DATABASE ARCHITECTURE</div> <ul style="list-style-type: none"> • DATABASE ARCHITECTURE AND FACTS INCLUDED IN RULE BASE 	<div>DATABASE ARCHITECTURE</div> <ul style="list-style-type: none"> • ARCHITECTURE REPRESENTED IN A LOGICAL TAXONOMY OF FRAMES/OBJECTS • APPLICATION VIEWS AUTOMATICALLY CREATED BY SELECTING SPECIFIC GOALS AND OBJECTS • CONTEXT SUPPORTED BY INHERITANCE IN DATA STRUCTURE • PARALLEL DATA SEARCH SUPPORTED BY MULTIWORLD REASONING
<div>REASONING PROCESS</div> <ul style="list-style-type: none"> • GOAL DRIVEN BACKWARD CHAINING 	<div>REASONING PROCESS</div> <ul style="list-style-type: none"> • GOAL DRIVEN BACKWARD CHAINING AND DATA DRIVEN FORWARD CHAINING CONCURRENTLY
<div>QUERY FORMULATION</div> <ul style="list-style-type: none"> • QUERY FORMULATION TO DBMS SUPPORTED BY NATURAL LANGUAGE QUERY PROCESSOR BETWEEN EXPERT SYSTEM AND DBMS 	<div>QUERY FORMULATION</div> <ul style="list-style-type: none"> • QUERY FORMULATION TO DBMS SUPPORTED BY NATURAL LANGUAGE QUERY PROCESSOR BETWEEN EXPERT SYSTEM AND DBMS

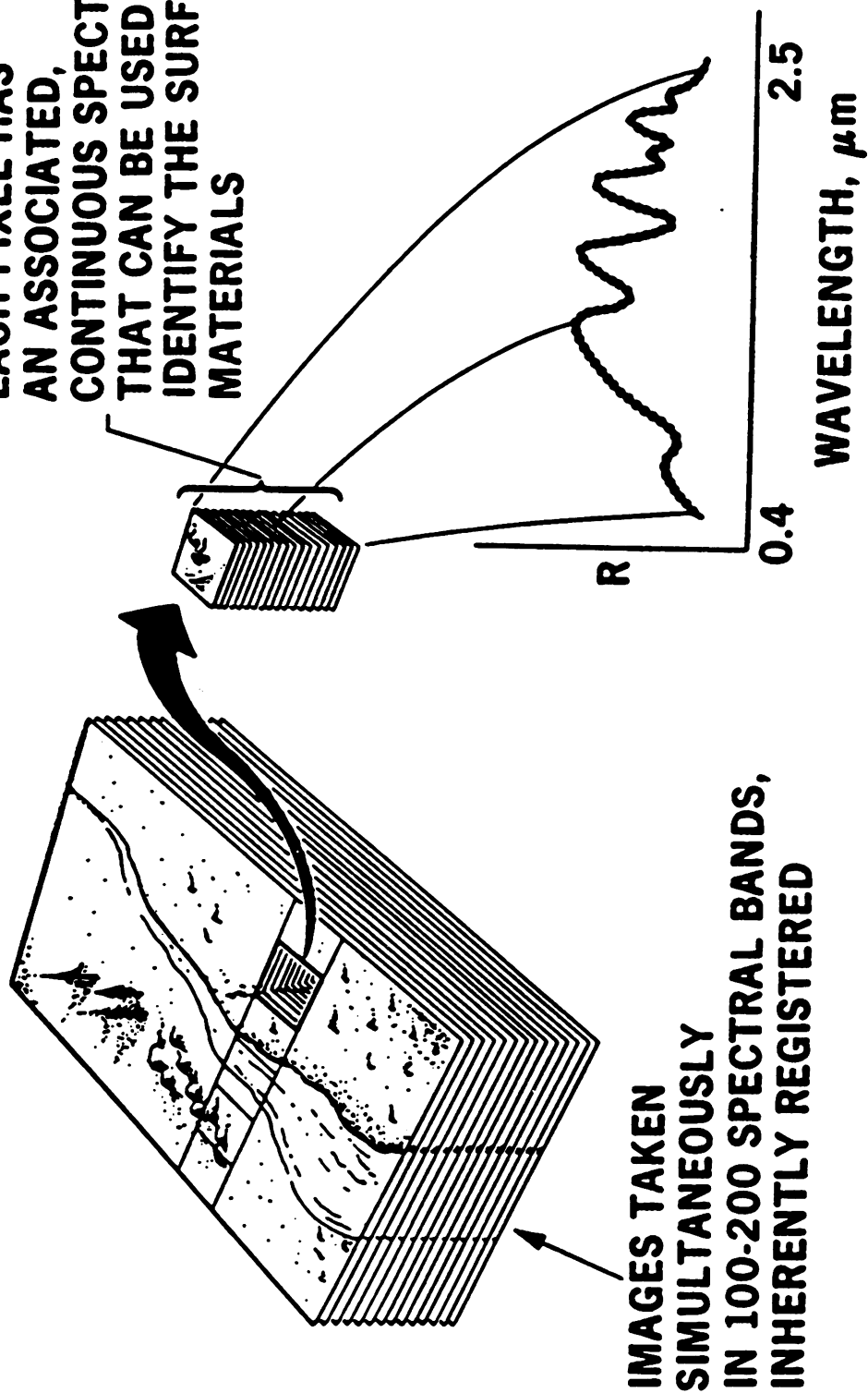
**AN EXPERT SYSTEM
FOR THE ANALYSIS OF
IMAGING SPECTROMETER DATA**

JPL

GARY C . BORCHARDT

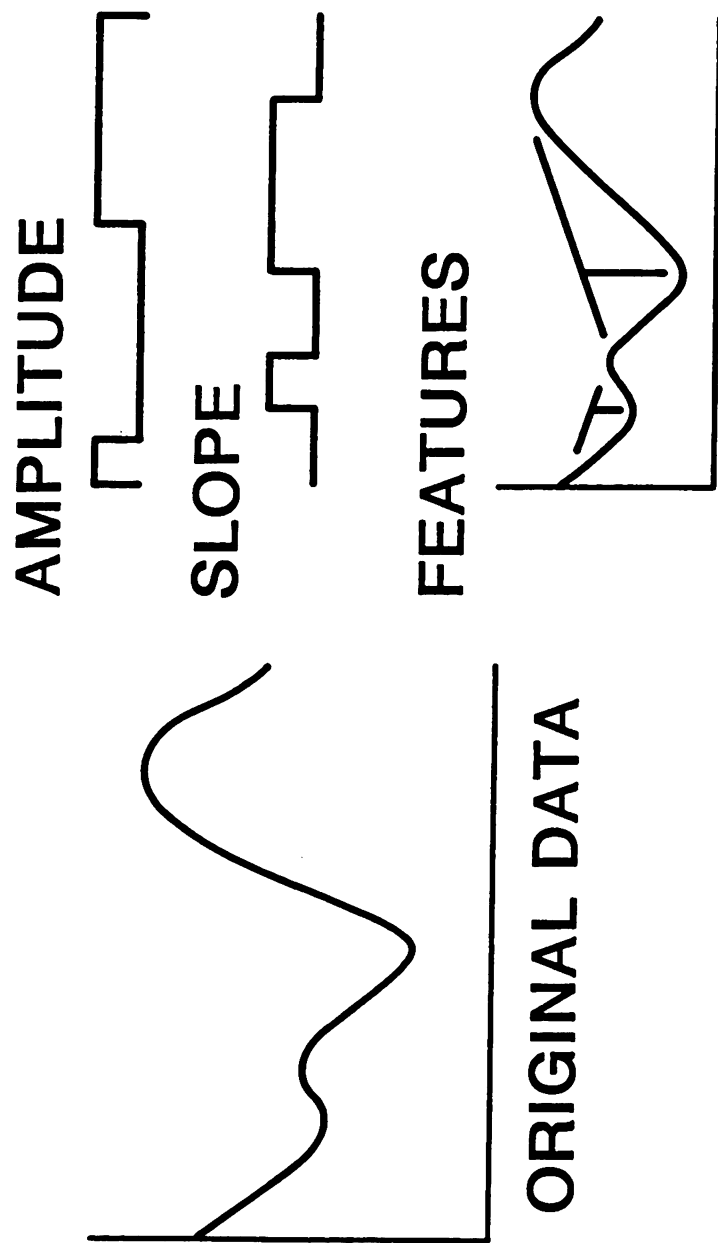
**JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA**

**EACH PIXEL HAS
AN ASSOCIATED,
CONTINUOUS SPECTRUM
THAT CAN BE USED TO
IDENTIFY THE SURFACE
MATERIALS**



**IMAGES TAKEN
SIMULTANEOUSLY
IN 100-200 SPECTRAL BANDS,
INHERENTLY REGISTERED**

JPL REPRESENTATION OF SPECTRAL DATA



JPL SUPPLEMENTARY INFORMATION

GEOLOGY/MINERALOGY:

**MINERAL CLASSIFICATIONS,
ABUNDANCE, STABILITY,
INTERASSOCIATIONS.**

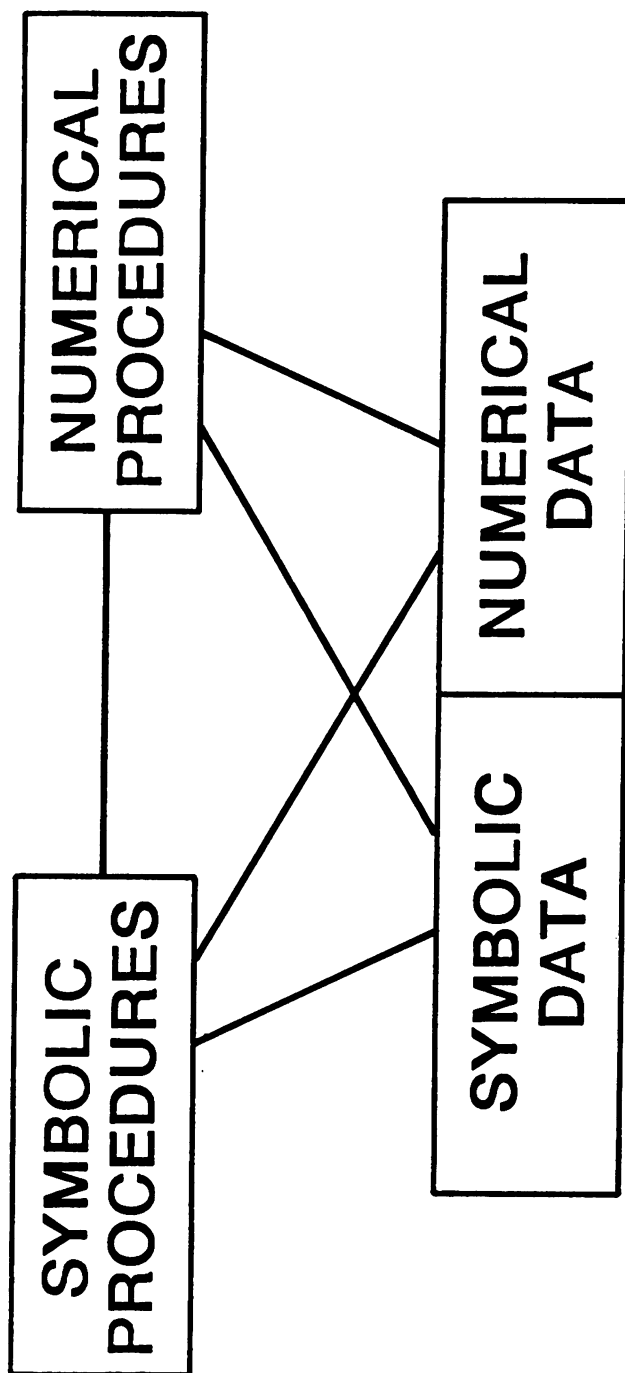
FROM THE USER:

EXPECTATIONS, SUGGESTIONS.

FROM THE IMAGE DATA:

**REGIONS OF SIMILARITY,
ADJACENCIES.**

JPL **STAR** (SIMPLE TOOL FOR AUTOMATED REASONING)



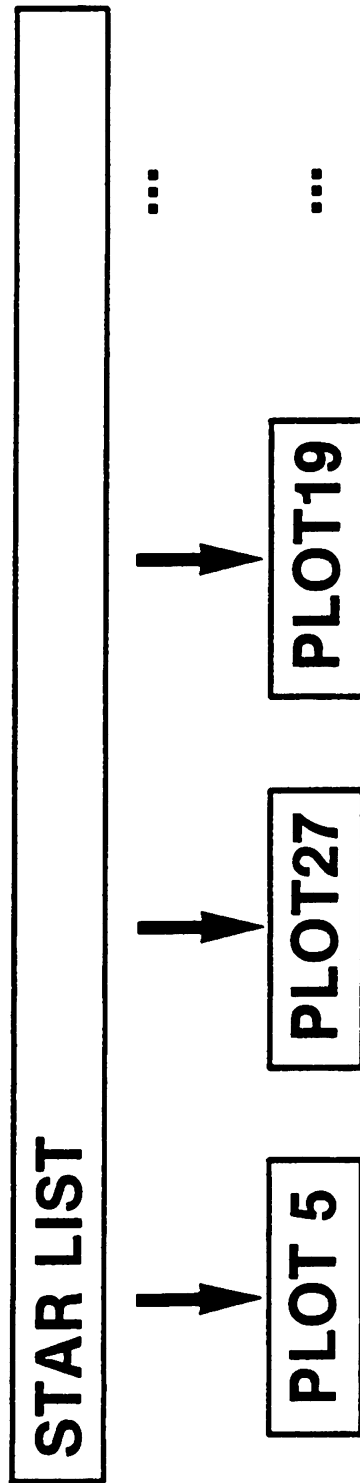
STAR DATA STRUCTURES (UNITS)

NUMBERS	3, -27, 100.4,
TOKENS	ALUMINUM, MULTIPLY,
STRINGS	"measure of similarity",
LISTS	[0.7 0.6 0.5], [],
RECORDS	{time → 8 value → true },
EXPRESSIONS	+(2 3), append([2 3] [4 5]),
CONNECTIONS	^C_ROUTINE, ^HASH_TABLE.

JPL

**CANDIDATES ([^PLOT5 ^PLOT27 ^PLOT19 ...]
^PLOT4 15 BINARY)**

→ [^PLOT5 ^PLOT19 ...]



SAMPLE STAR CONSTRUCTS

```

{name -> BIOTITE
member_of -> class
subclass_of -> mica
members -> [biotite_1 biotite_2]
subclasses -> []
abundance -> very_common
stability -> unstable
associated_with ->
    [muscovite orthoclase amphibole]
}

```

```

{name -> BIOTITE_1
member_of -> biotite
data -> ^PLOT_305460
}

```

```

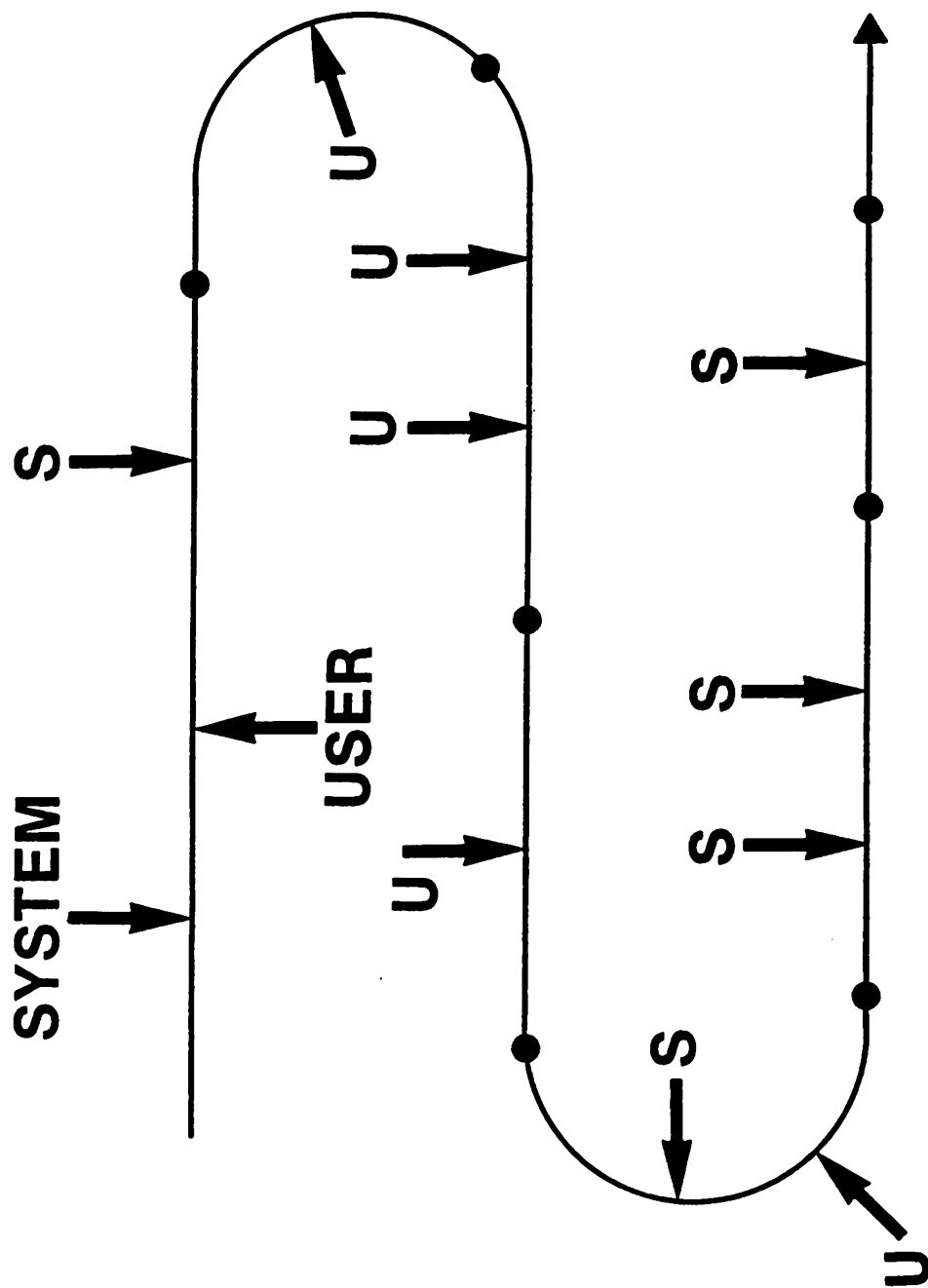
{name -> BIOTITE_2
member_of -> biotite
data -> ^PLOT_306520
}

```

```

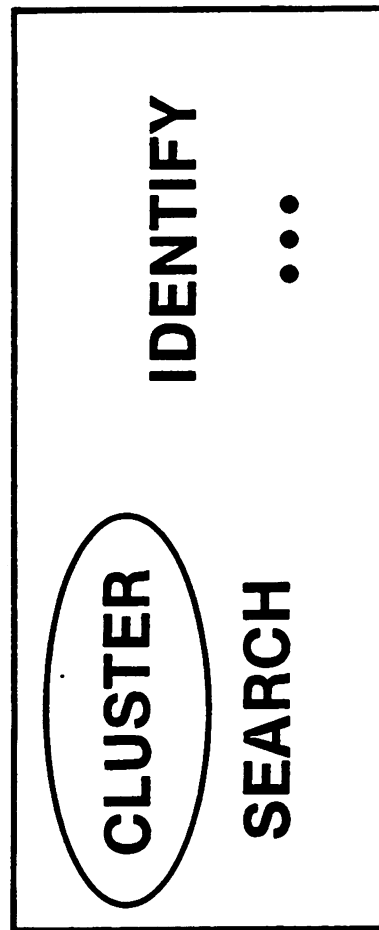
{name -> DISTANCE
member_of -> c_application_function
comment ->
"      (^PLOT1 ^PLOT2 NUMBER1) => NUMBER
"
"      Measures the distance between the
"encodings of two plots, ^PLOT1 and ^PLOT2.
"The particular encoding method and distance
"measure used is determined by the value of
"NUMBER1."
n_arguments -> 3
algorithm -> ^C_DISTANCE_FUNCTION
}

```

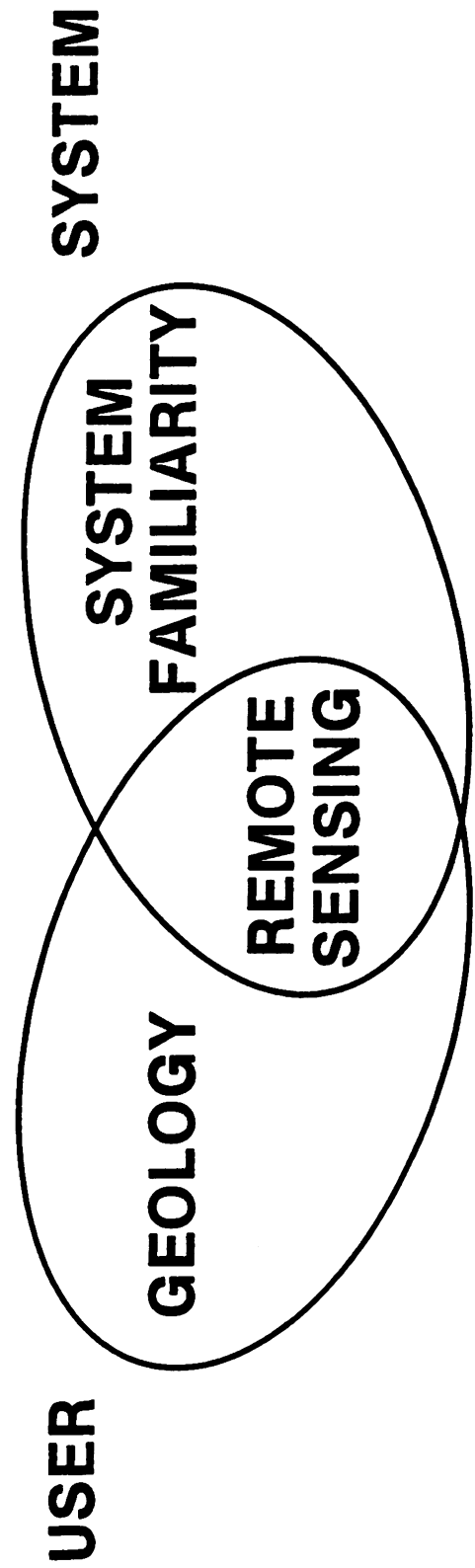


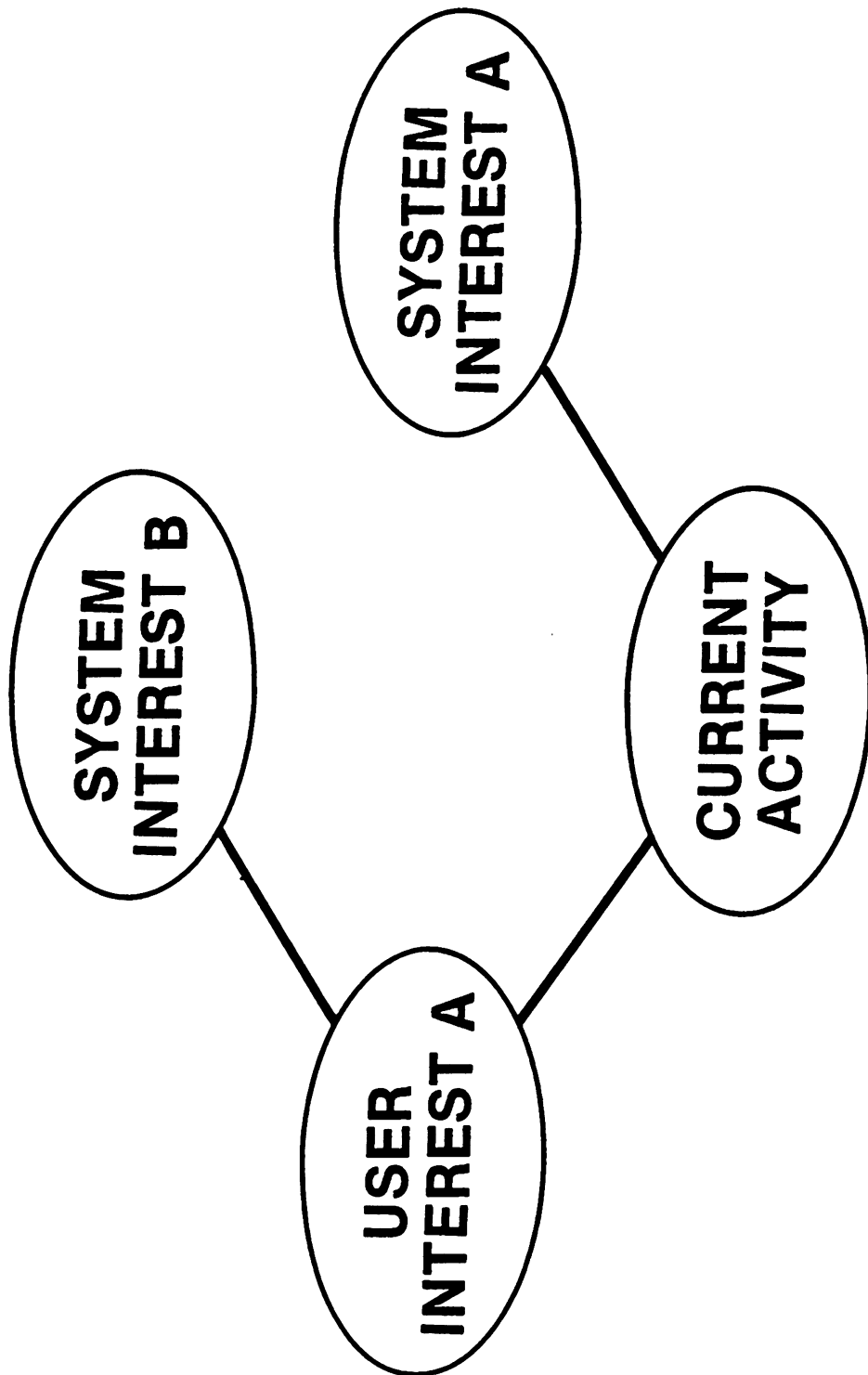
JPL

FOCUS OF ACTIVITY



DECISION AREAS OF INTEREST





USER DESCRIBES ENVIRONMENT
AND EXPECTED MINERALS



USER VIEWS CROSS-SECTIONS
OF THE DATA TO IDENTIFY
REGIONS OF INTEREST



SYSTEM AUTOMATICALLY
DETERMINES PARAMETERS
FOR CLUSTERING OPERATION



SYSTEM PERFORMS INITIAL
CLUSTERING OPERATION



USER ALTERS CLUSTERING
PARAMETERS AND DIRECTS
SYSTEM TO RECLUSTER



...

JPL ORGANIZATION OF THE SPECTRUM SYSTEM

MIXED-INITIATIVE CONTROL
SYMBOLIC FUNCTIONS AND RULES
NUMERICAL FUNCTIONS



SYMBOLIC INFORMATION BASE	
SPECTRAL LIBRARY	IMAGE DATA

FAULT-TOLERANT SOFTWARE: MODELING AND VALIDATION

Dave E. Eckhardt, Jr.
NASA Langley Research Center

NASA
Computer Science / Data Systems
Technical Symposium
November 18-20, 1986

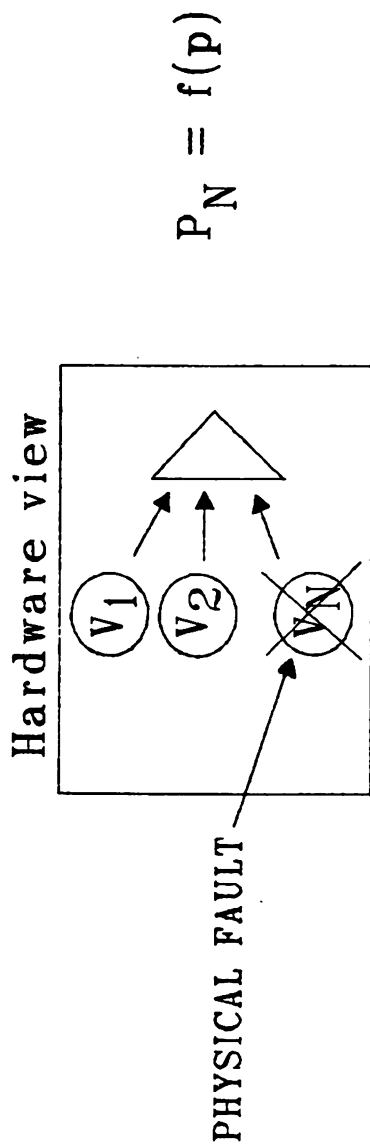
BACKGROUND

- Advocacy/Research - 1975
 - Redundancy as a defense against residual faults in critical software
- Application
 - Airbus Industries A310 slat and flap control
 - Swedish state railroads traffic control system
 - Boeing 737-300 critical flight control functions
 - Boeing 757 yaw damper and stabilizer trim systems
 - Atomic Energy of Canada nuclear reactor shutdown system
 - NASA Space Shuttle mission critical functions
- Issues
 - Costs, overhead/performance, adjudication, applicability, independence
 - Fundamental issue, coincident failures
 - Is software redundancy an effective strategy for achieving high reliability?

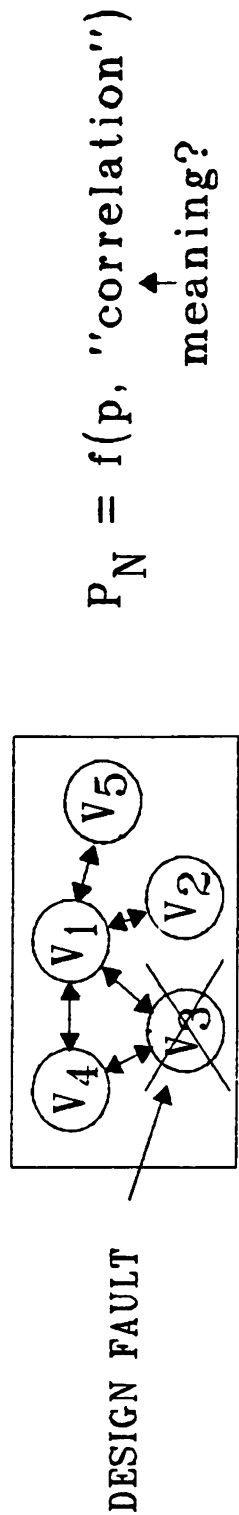
RESEARCH OBJECTIVES

- **Modeling**
Develop model for analyzing redundant software where components are subject to coincident failure.
- **Experiments**
Provide empirical data on the effectiveness of software redundancy (reliability gains).
- **Application**
Determine the applicability of systems theory to fault-tolerant software techniques.

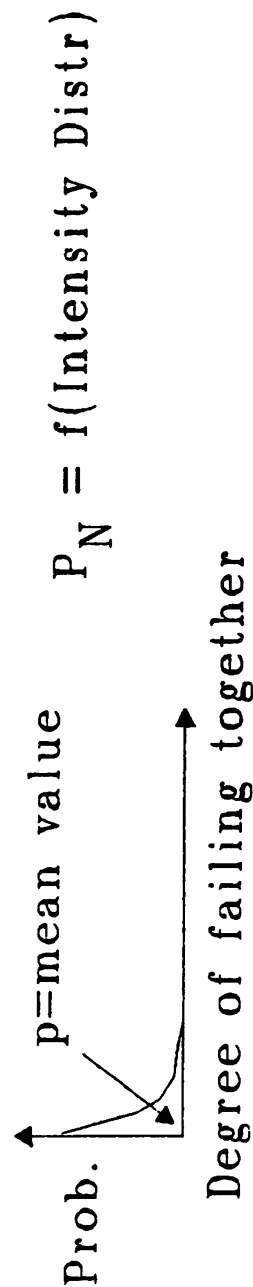
MODELING REDUNDANCY



Are there complex dependencies among software versions?



A distribution of failure intensity has meaning



COINCIDENT ERROR MODEL: A THEORETICAL BASIS FOR ANALYZING REDUNDANT SOFTWARE

Under the conditions that:

- (1) components are selected from a random sample
 - (2) inputs are from a common usage distribution Q
- the expected probability of system failure P_N is:

$$P_N = \int_{t=\frac{(N+1)}{2}}^N \sum \binom{N}{t} y^t (1-y)^{N-t} dG(y)$$

$$G(y) = \int \quad \quad \quad dQ \quad \quad \quad \text{Intensity Distribution}$$

$$\{ x: \theta(x) \leq y \}$$

$$\theta(x) = \text{Intensity Function}$$

COINCIDENT ERROR MODEL PROVIDES ANALYSIS OF:

- When redundancy is effective
- Limitations of redundancy
- Optimum level of redundancy
- Meaning of independence
- Impact of unclear, misleading specifications

What is the impact of a misleading specification on redundant software?

PAST RESPONSE:

(after much agonizing about how to address problem)
"It makes the software worse"

CURRENT RESPONSE:

The concept of an intensity distribution provides a way to think about the problem.

What is the intensity coefficient?
(propensity to misinterpret)

What is the probability that an event will invoke the error?



Suppose $g(.6) = 10^{-4}$ and $g(0) = 1 - 10^{-4}$

Number Versions	P_N	
	CEM Model	Independence Model
1	6.0×10^{-5}	6.0×10^{-5}
3	6.5×10^{-5}	1.1×10^{-8}
5	6.8×10^{-5}	2.2×10^{-14}

What causes redundancy to be an incorrect strategy?

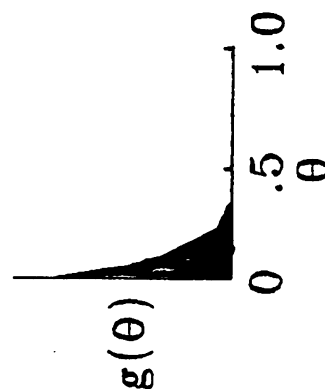
When is redundancy a more effective strategy than relying on a single version?

PAST RESPONSE: (Independence model)

$$p < .5 \iff p_N < p \quad (\text{and surely } p < .5)$$

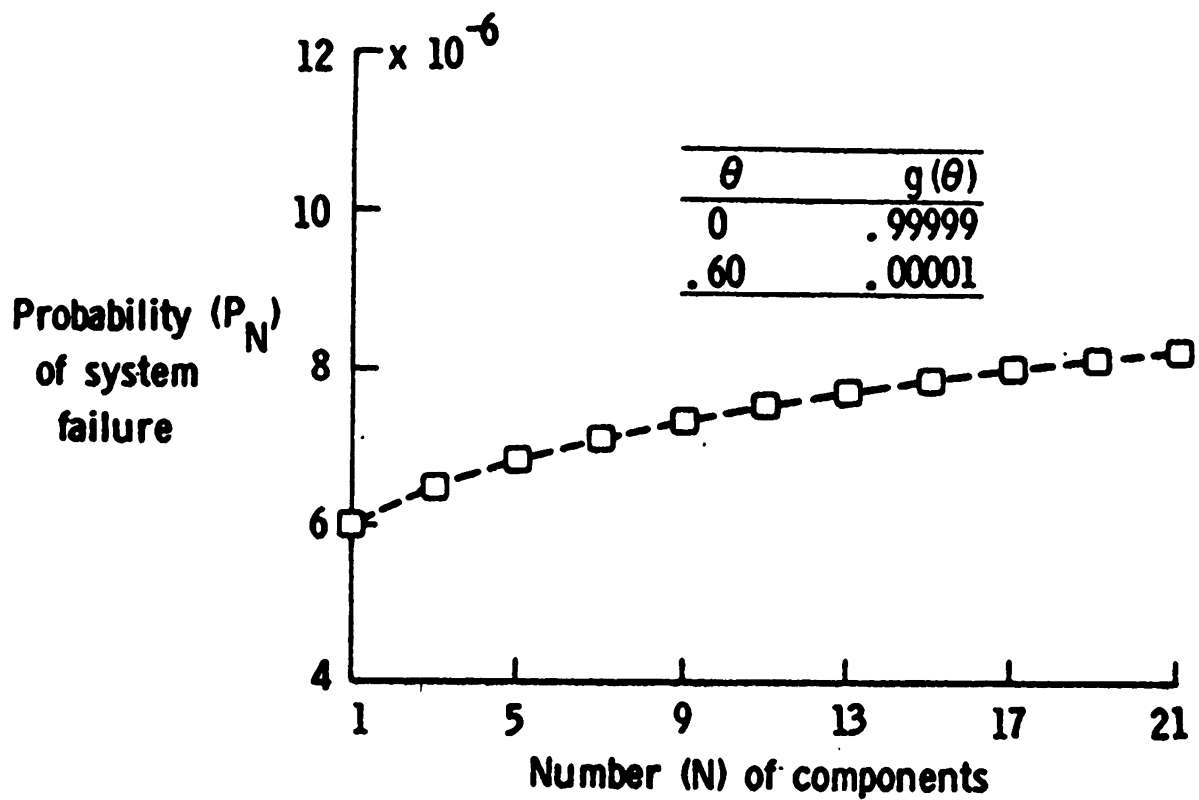
CURRENT RESPONSE: (Coincident Error Model)

If, for all feasible input conditions, the theoretical proportion of incorrect versions is less than .5 (i.e. a minority fail), this is sufficient (but not necessary) for redundancy to improve reliability.



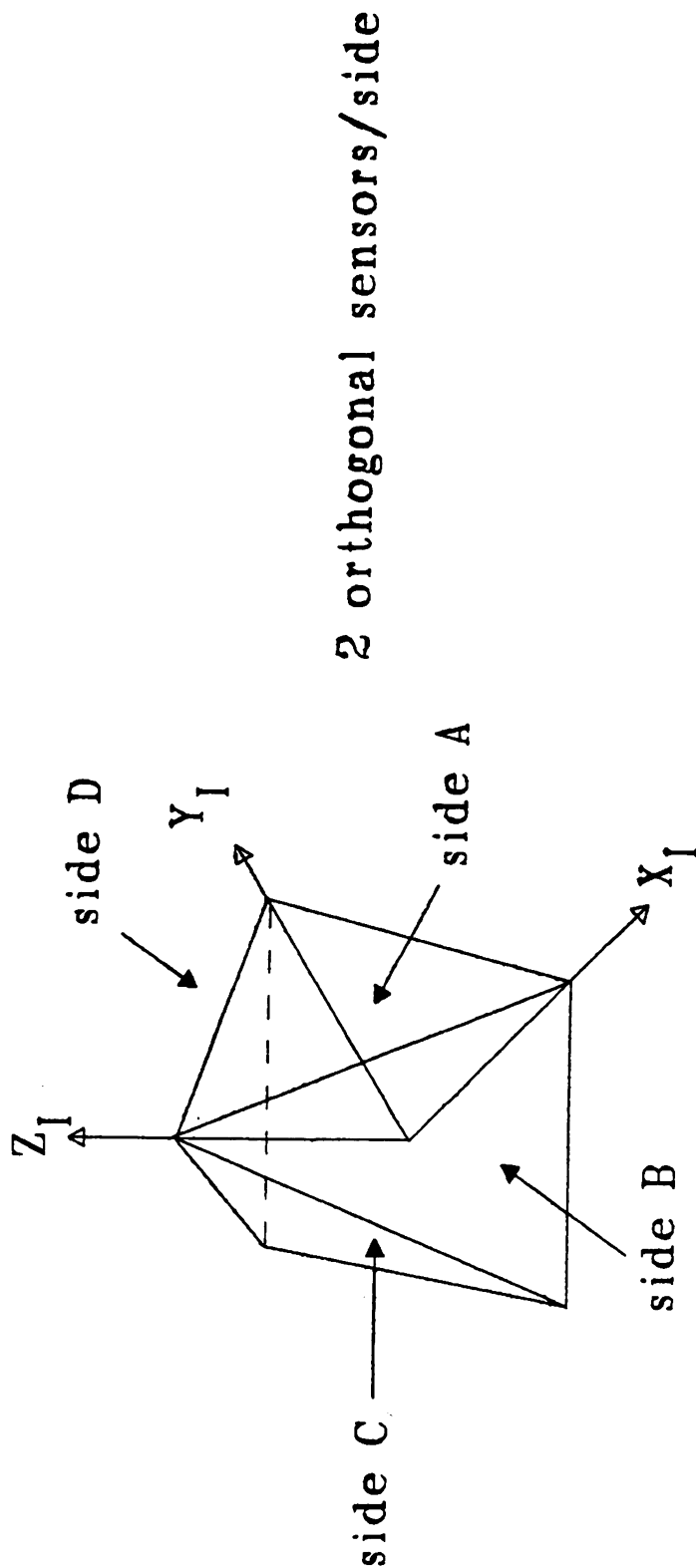
i.e intensity mass function
bounded by .5

Further, $p < .5 \Rightarrow p_N < p$



FDI Logic Portion of the Redundancy Management & Vehicle State Estimation Software for a Skewed Sensor Array

Given: 6 edge relationships (AB, AC, AD, BC, BD, CD)
on 4 faces (A, B, C, D). Determine faulty sensors.



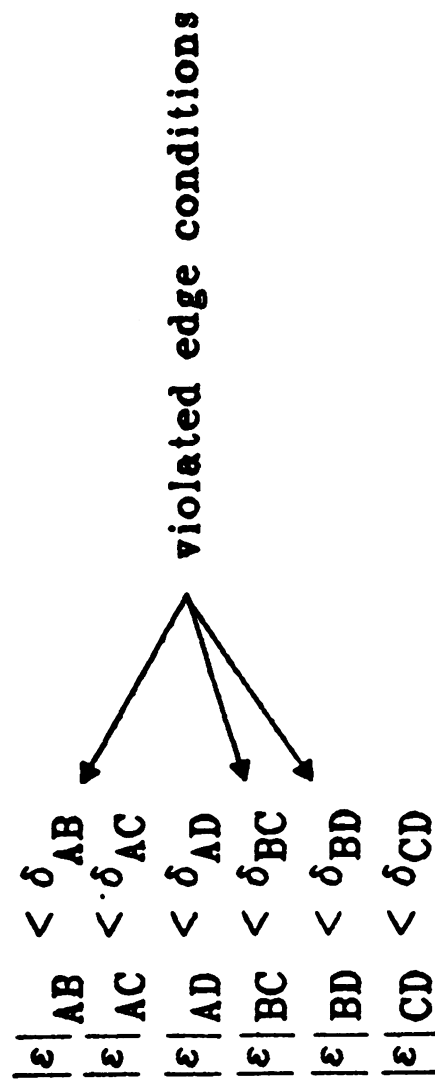
FDI Specification

Section 2. Functional Requirements

... "You are to assume that at most a single additional sensor will fail for a given execution. Therefore the face containing the failed sensor can be identified by comparing the faces pairwise and eliminating the face common to all out of tolerant condition."....

Section 8. Edge Vector Test

"Sensor failure detection and isolation is achieved by evaluating the status of the edge vector comparison tests:



For instance, if the second, third, and sixth relations are satisfied while the first, fourth, and fifth relations are violated, then either the x-accelerometer or y-accelerometer on face B must have failed."

FDI Interpretation

All sensors initially working		
Group	Number of edge violations for face failure	Group size
1	1, 2, or 3	2
2	2 or 3	2
3	3	7
4	2 or 3 (1 causes all sensors to fail)	5
5	3 (1 or 2 causes all sensors to fail)	1
6	could not determine	3
Total		20

THE IMPLEMENTATION AND USE OF ADA
FOR FAULT-TOLERANT DISTRIBUTED SYSTEMS

NASA GRANT #NAG-1-260

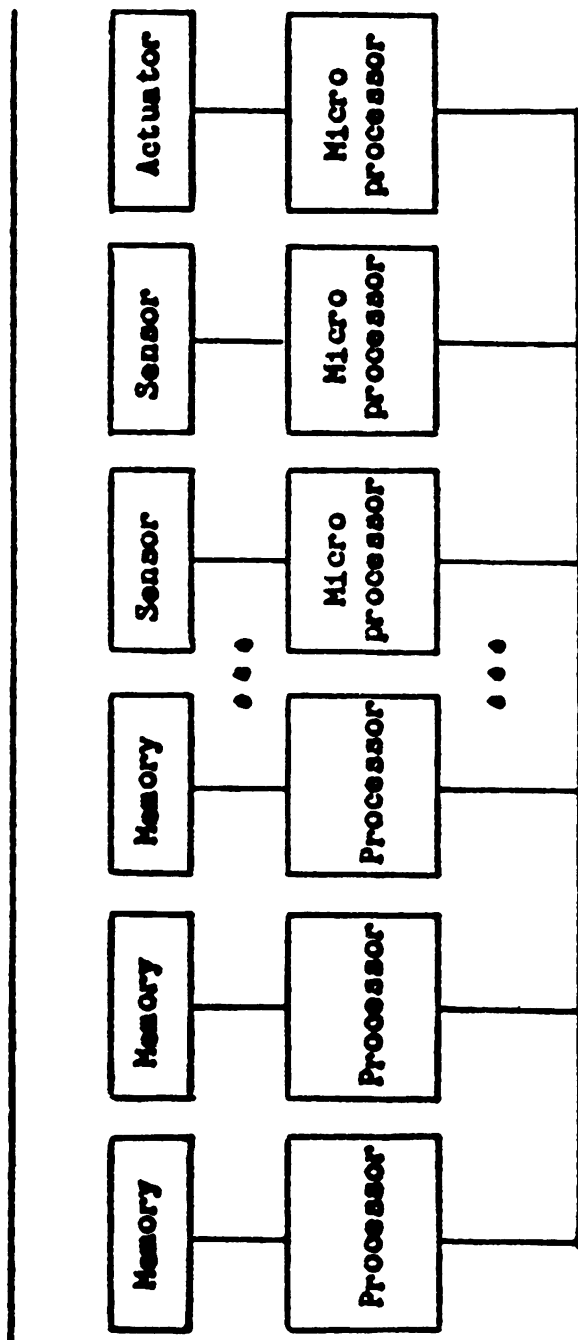
WITH UNIVERSITY OF VIRGINIA

PRINCIPAL INVESTIGATOR:

DR. JOHN C. KNIGHT

PRESENTED BY: E. H. SENN
DATE: NOVEMBER 18-20, 1986

- 0 INITIAL REQUIREMENT AND ASSUMPTIONS
- REQUIREMENT: TO PROGRAM A DISTRIBUTED COMPUTER SYSTEM USING ADA,
AND TO ACHIEVE SOFTWARE RECOVERY AND CONTINUATION OF SERVICE AFTER
FAILURE OF NODE PROCESSORS IN THE NETWORK
- ASSUMPTIONS:
 - 0 A GENERAL DISTRIBUTED SYSTEM ARCHITECTURE
 - 0 A REPLICATED NETWORK COMMUNICATIONS STRUCTURE
 - 0 EXISTING INTRA-PROCESSOR ERROR DETECTION
 - 0 EXCESS PROCESSOR CAPACITY TO ALLOW SAME SERVICE RECOVERY FOLLOWING
PROCESSOR FAILURES
 - 0 A COMMUNICATIONS PROTOCOL WHICH CONFORMS TO ISO STANDARD SEVEN-
LAYER MODEL
 - 0 NO SYNTACTICAL CHANGES TO ADA



Communications Network

Figure 1 - Distributed Architecture

0 CURRENT WORKING METHODS AND APPROACHES

- ASSUMES A SINGLE ADA PROGRAM CONSISTING OF MULTIPLE TASKS
DISTRIBUTED ACROSS AVAILABLE PROCESSORS
- REQUIRES USER-CONTROLLED TASK DISTRIBUTION METHOD
- USES TASK ABORT SEMANTICS AND EXCEPTION INTERRUPTS TO SIGNAL
PROCESSOR FAILURE TO SYSTEM
- TRANSPARENT VERSUS CONTROLLED TASK RECOVERY
 - 0 TRANSPARENT/ WOULD ALWAYS PROVIDE SAME SERVICE RECOVERY
 - 0 CONTROLLED/ COULD PROVIDE ALTERNATE OR REDUCED SERVICE
- PASSIVE VERSUS ACTIVE FAILURE DETECTION METHODS
 - 0 PASSIVE/DEPENDENT ON TIME-OUTS AND ASSUMPTIONS
 - 0 ACTIVE/USES PERIODIC "HEARTBEAT" SOFTWARE MESSAGES AND GENERATED
TASK ABORT (FAILED) MESSAGES TO SIGNAL PROCESSOR FAILURE AND
INITIATE RECOVERY

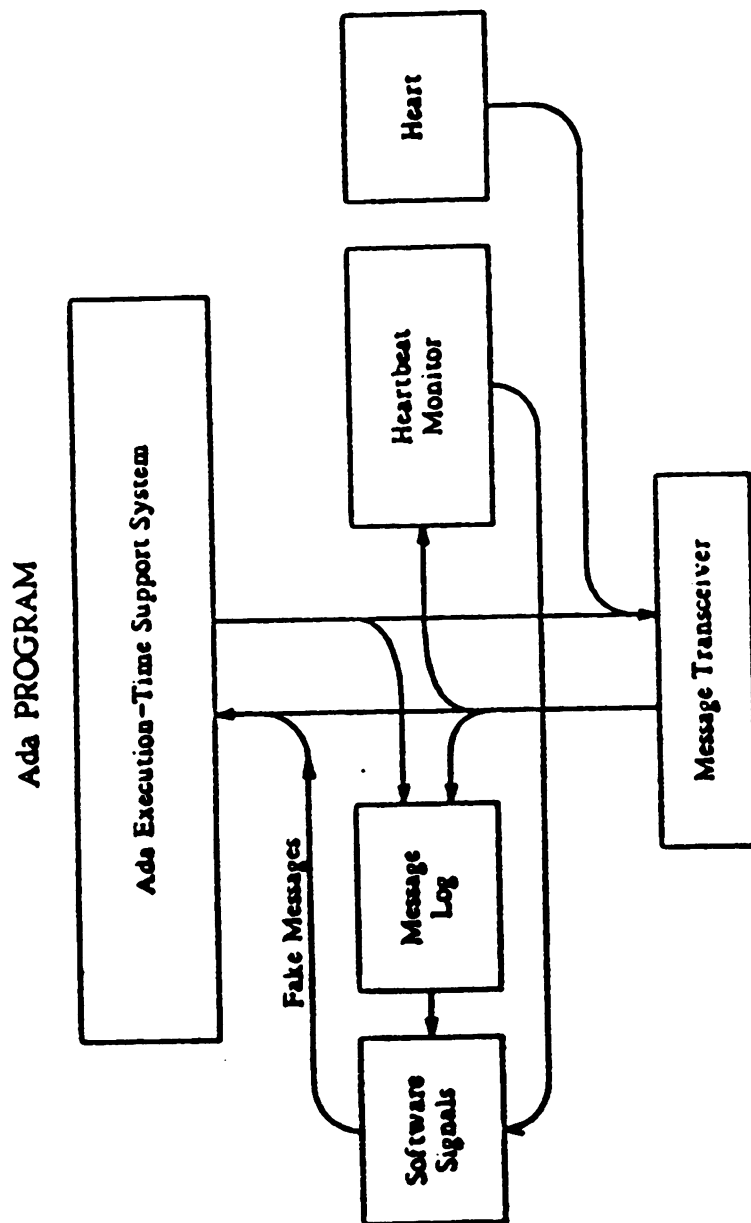


Fig. 2. Implementation Model For Each Processor

0 CURRENT TESTED STATUS AND ADA PROBLEMS

- TESTED STATUS

- 0 A USABLE FI/ADA TESTBED EXISTS ON A U. VA. VAX 11/750
- 0 USES ENHANCED RUN-TIME SUPPORT, HEARTBEATS, TASK ABORTS,
AND GENERATED "FAKE" MESSAGES TO SIGNAL PROCESSOR FAILURE
AND INITIATE RECOVERY
- 0 PORTED TO A NETWORK OF APOLLO MICROS (UNSATISFACTORY)
- 0 PLANS TO PORT TO ANOTHER MICRO NETWORK (SUNS?)

- ADA PROBLEMS

- 0 NO PROVISION FOR CONTROLLED DISTRIBUTION OF TASKS
- 0 NO SYNTAX OR SEMANTICS FOR HANDLING PROCESSOR FAILURE
- 0 NO PROVISIONS FOR RECOVERY/CONTINUATION ACTIONS
 - DAMAGE ASSESSMENT ACTIVITIES
 - VALID DATA (RE) DISTRIBUTION/RECOVERY
 - TASK RECONFIGURATION AND RESTART

0 CONCLUSIONS:

- WE BELIEVE THE KNOWN ADA PROBLEMS CAN BE, AND ARE, RESOLVED BY THE PROPOSED MECHANISMS FOR HARDWARE FAILURE RECOVERY
- WE ARE PLANNING TO USE A SKELETON ATOPS FLIGHT CODE APPLICATION TO PROVE THE ADA/TESTBED WORKS AS EXPECTED
- ADA MAKES NO PROVISIONS FOR TOLERANCE TO SOFTWARE FAILURES
- JOHN KNIGHT IS PROPOSING SOME EXTENSIONS TO ADA TO SUPPORT BACKWARD-ERROR-RECOVERY FOR SOFTWARE APPLICATIONS FAILURES
- 0 CONVERSATIONS/FOR COMMUNICATION AND SYNCHRONIZATION
- 0 A DIALOG/FOR CONTROLLED PROCESS COMMUNICATIONS AND ROLLBACK
- 0 A COLLOQUY/A SET OF DIALOGS AND GLOBAL ACCEPTANCE TESTS

ARCHITECTURE RESEARCH AT ARC

DATA FLOW ARCHITECTURES

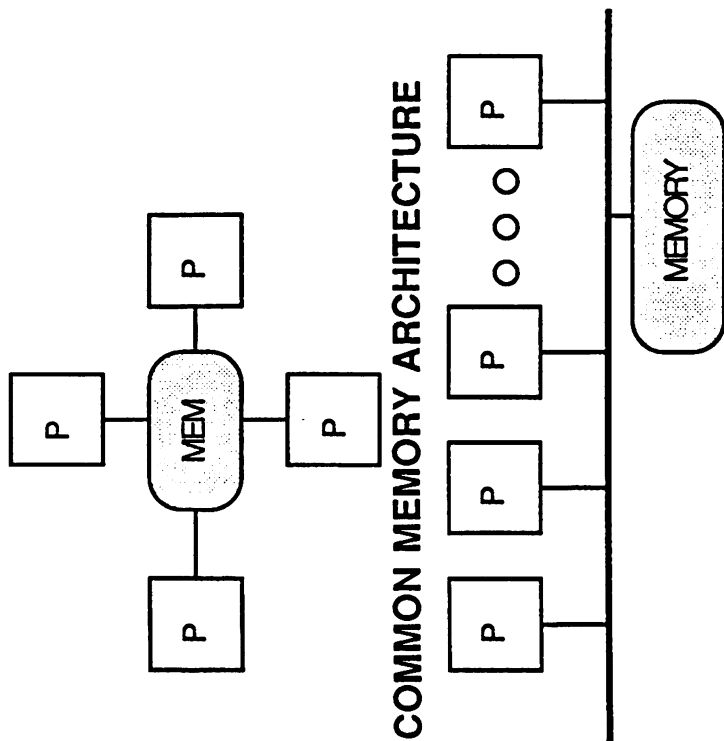
HOMOGENOUS MULTIPROCESSORS

HETEROGENEOUS MULTIPROCESSORS

PERFORMANCE PREDICTION TOOLS

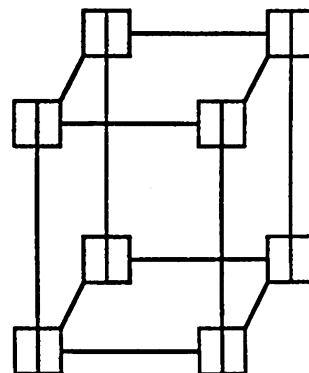
PROGRAMMING LANGAGES FOR MULTIPROCESSORS

COMPUTER ARCHITECTURES

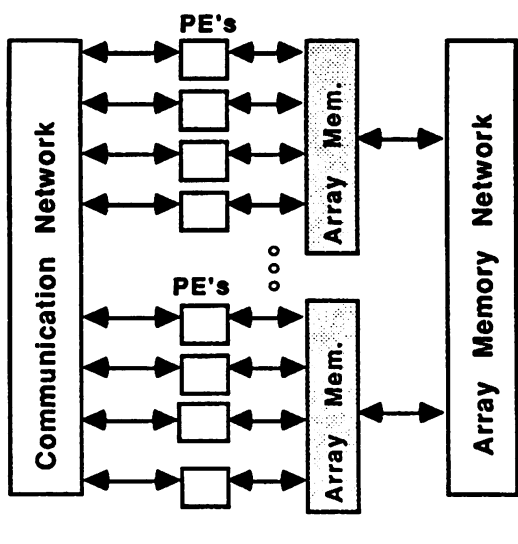


COMMON MEMORY ARCHITECTURE

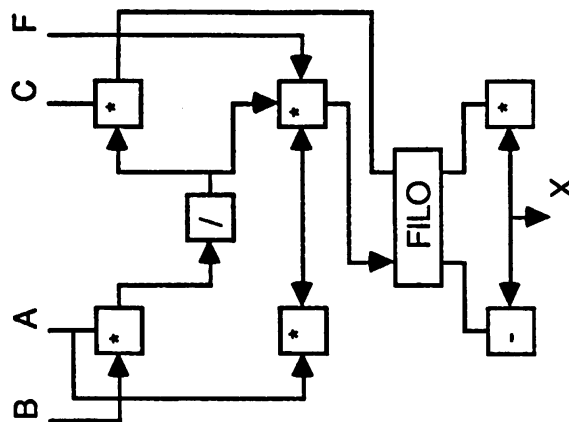
COMMON MEMORY BUS ARCHITECTURE



LOCAL MEMORY HYPERCUBE



DATA FLOW ARCHITECTURE



SYSTOLIC ARRAY ARCHITECTURE

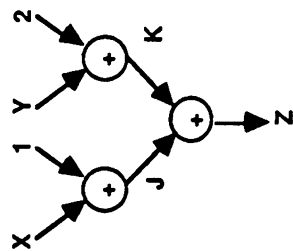
Code

J = X + 1
K = Y + 2
Z = J + K

Sequential

L R1,X
L R2,1
A R1,R2
L R2,Y
L R3,2
A R2,R3
A R1,R2
S R1,Z

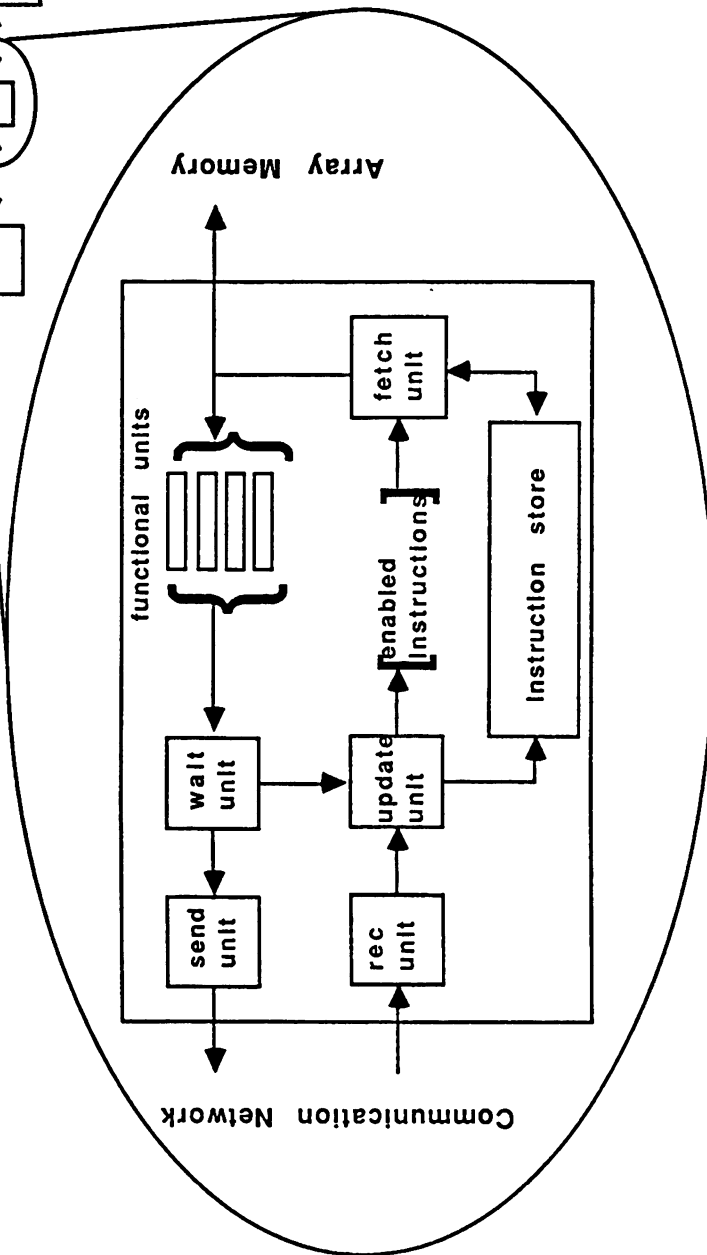
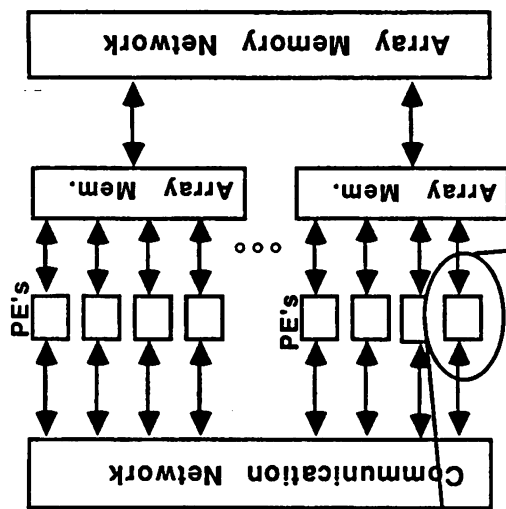
Data Flow



minimum execution
time of 8 cycles

minimum execution
time of 3 cycles

Architecture



DATA FLOW

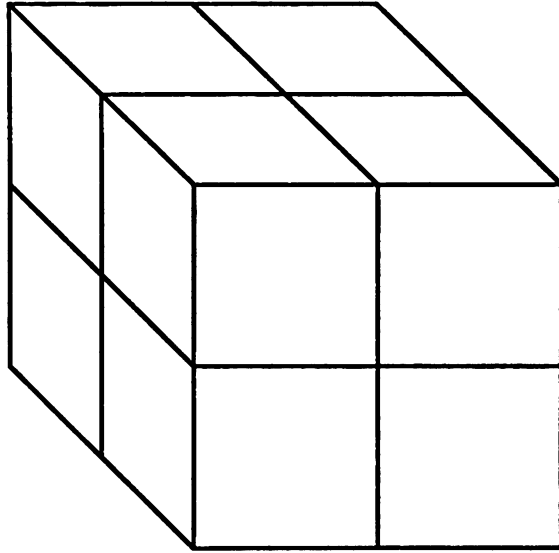
COMPLETED SIMULATOR

DEVELOPED INSTRUCTION PARTITIONER WHICH IS ARCHITECTURE SENSITIVE

UPDATE UNIT IS THE BOTTLENECK

CURRENTLY SIMULATING THE NAS KERNELS

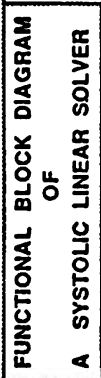
Mapping CFD Programs onto homogenous Multiprocessors



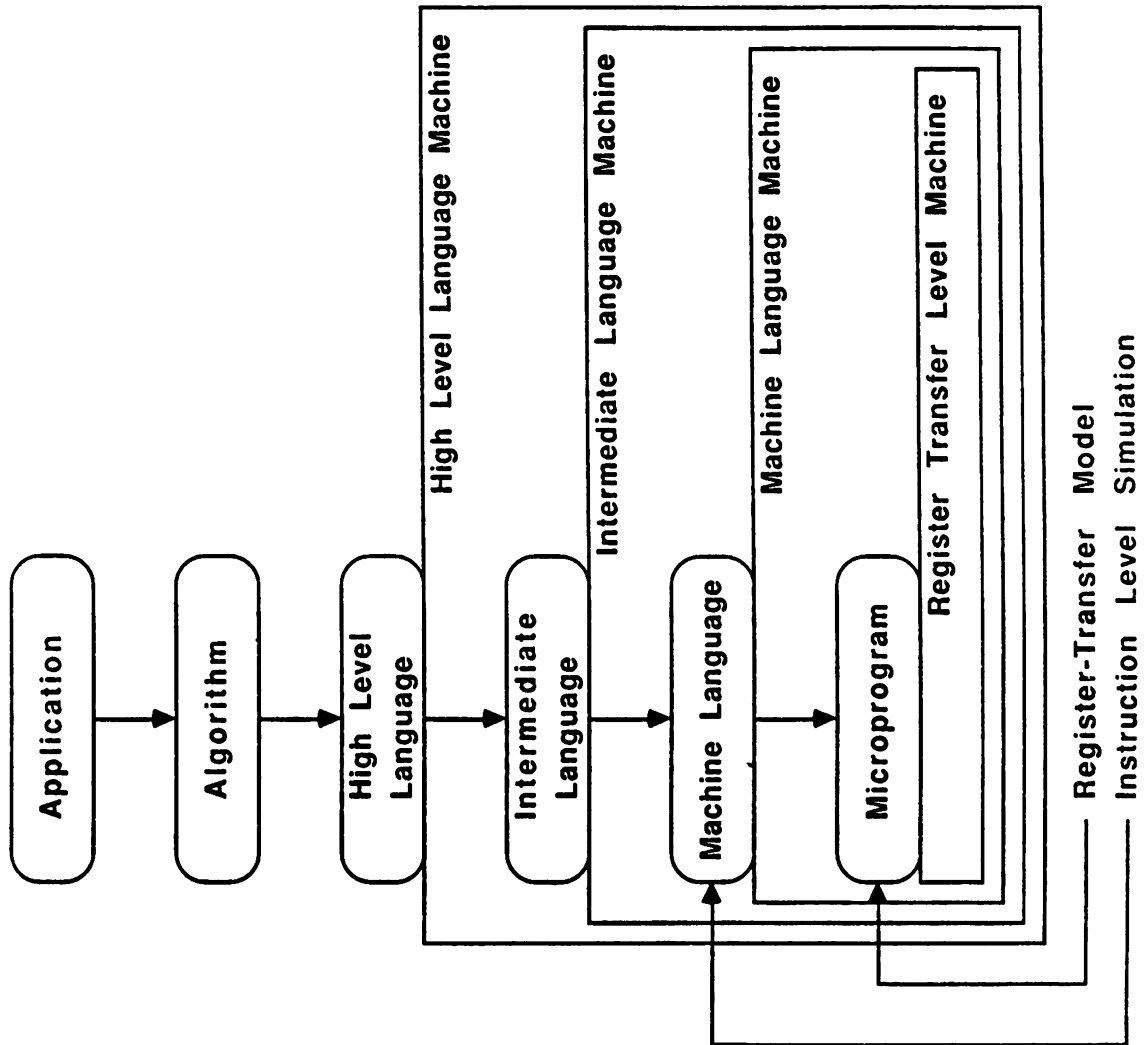
Spatially split algorithms (e.g. TWING, ARC3D, and LES) have been mapped onto common memory multiprocessors like the CRAY X-MP and CRAY 2.

Have mapped FLO52 onto the IPSC

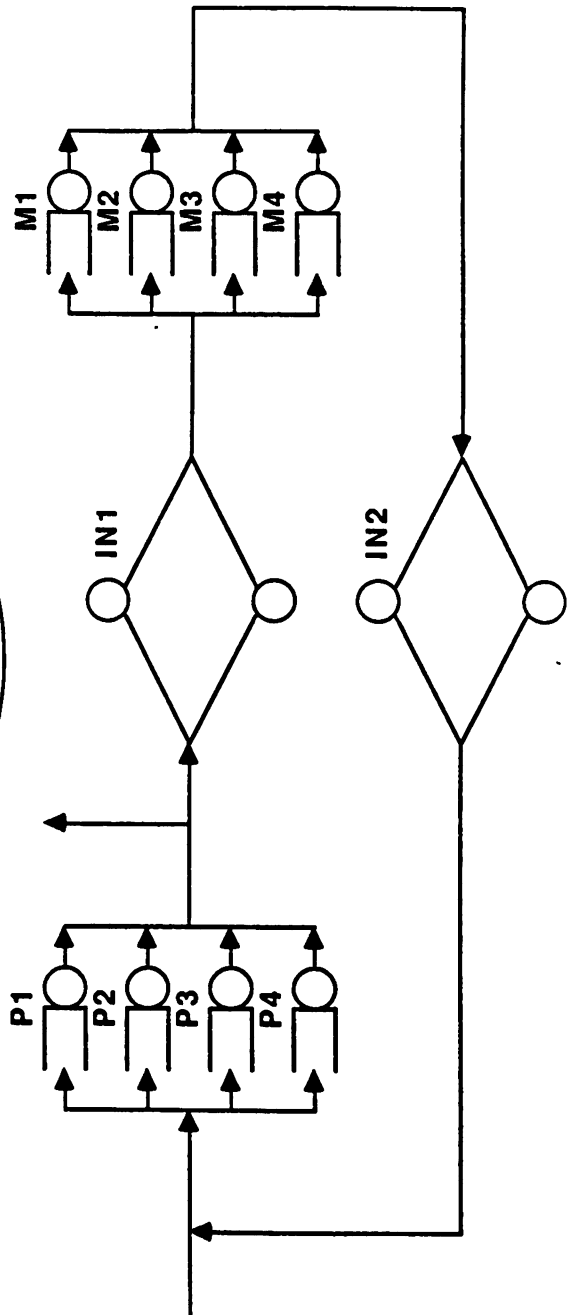
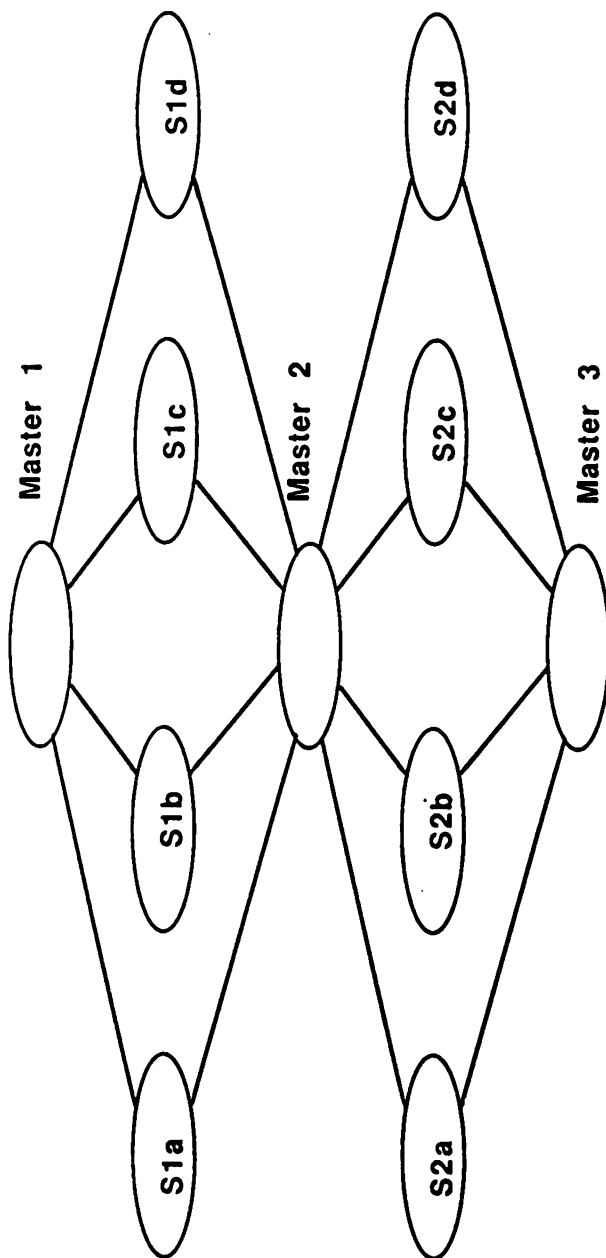
A LOW COST, HIGH SPEED



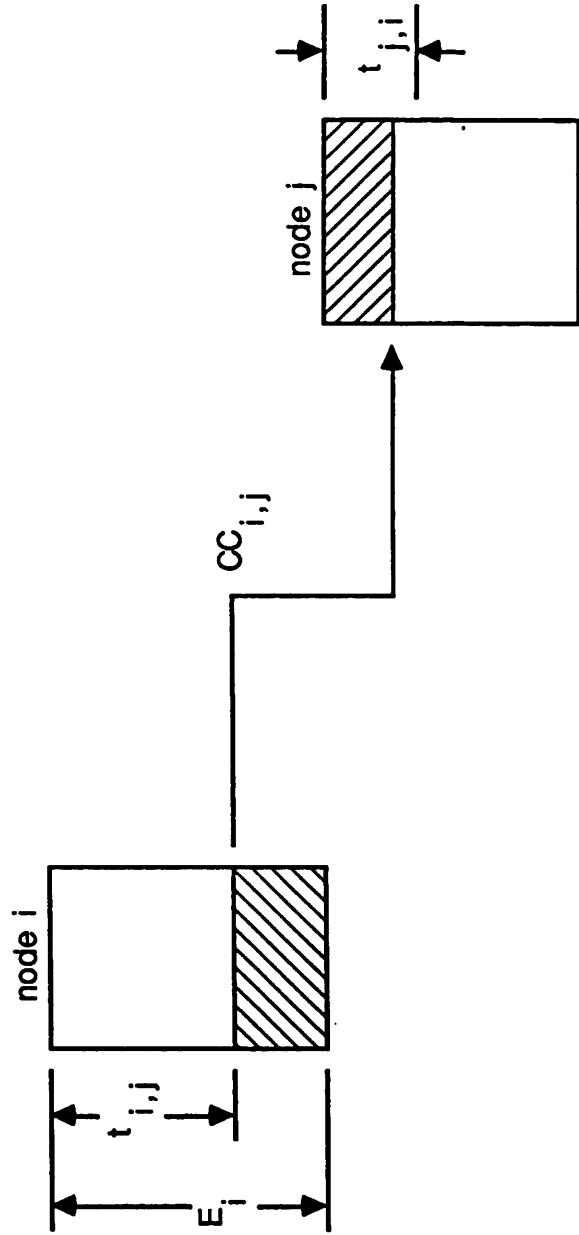
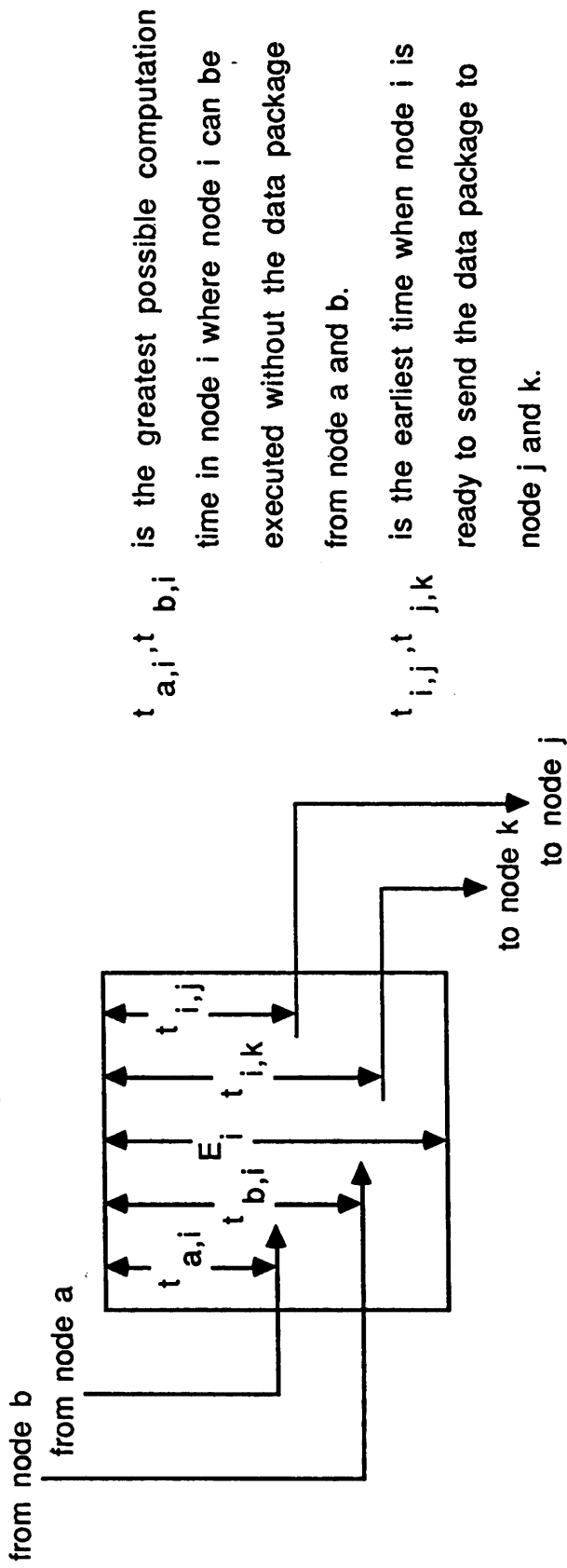
Level of Performance Modeling



Queueing Network Models

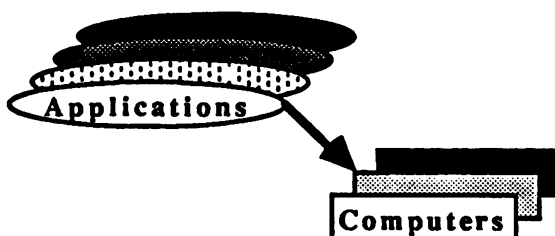


Parallelism Detection

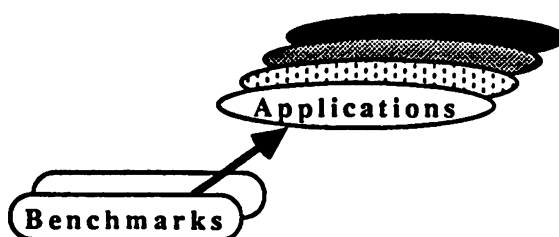
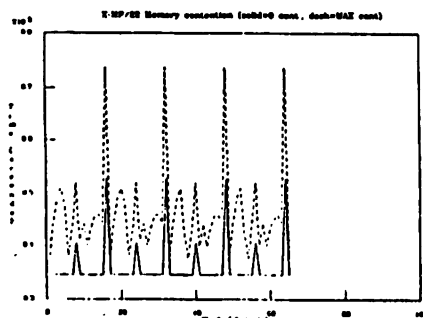
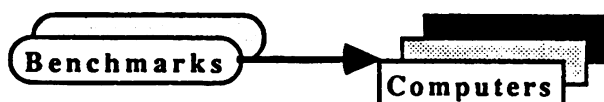


$$\text{Benefit} = [(E_i - t_{i,j}) + t_{j,i}] - CC_{i,j} = \text{saving from parallelism} - \text{communication overhead}$$

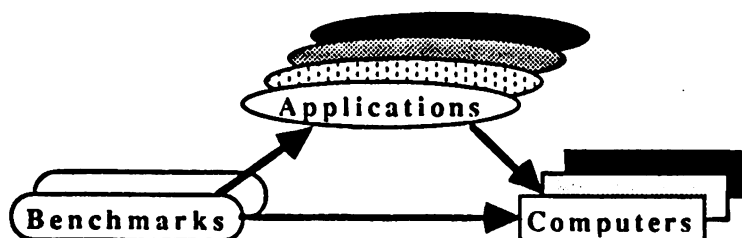
Performance Measurement Research



Livermore & NAS loops, Whetstones, Dhrystones



Op counts, execution profiles, . . .



PROGRAMMING LANGUAGES FOR MULTIPROCESSORS

MULTITASKING SUBROUTINES

**SUBROUTINES TO CONTROL TASKS, FLAGS, AND LOCKS
PROVIDED BY CRAY RESEARCH BUT UNNATURAL FOR USERS**

MICROTASKING

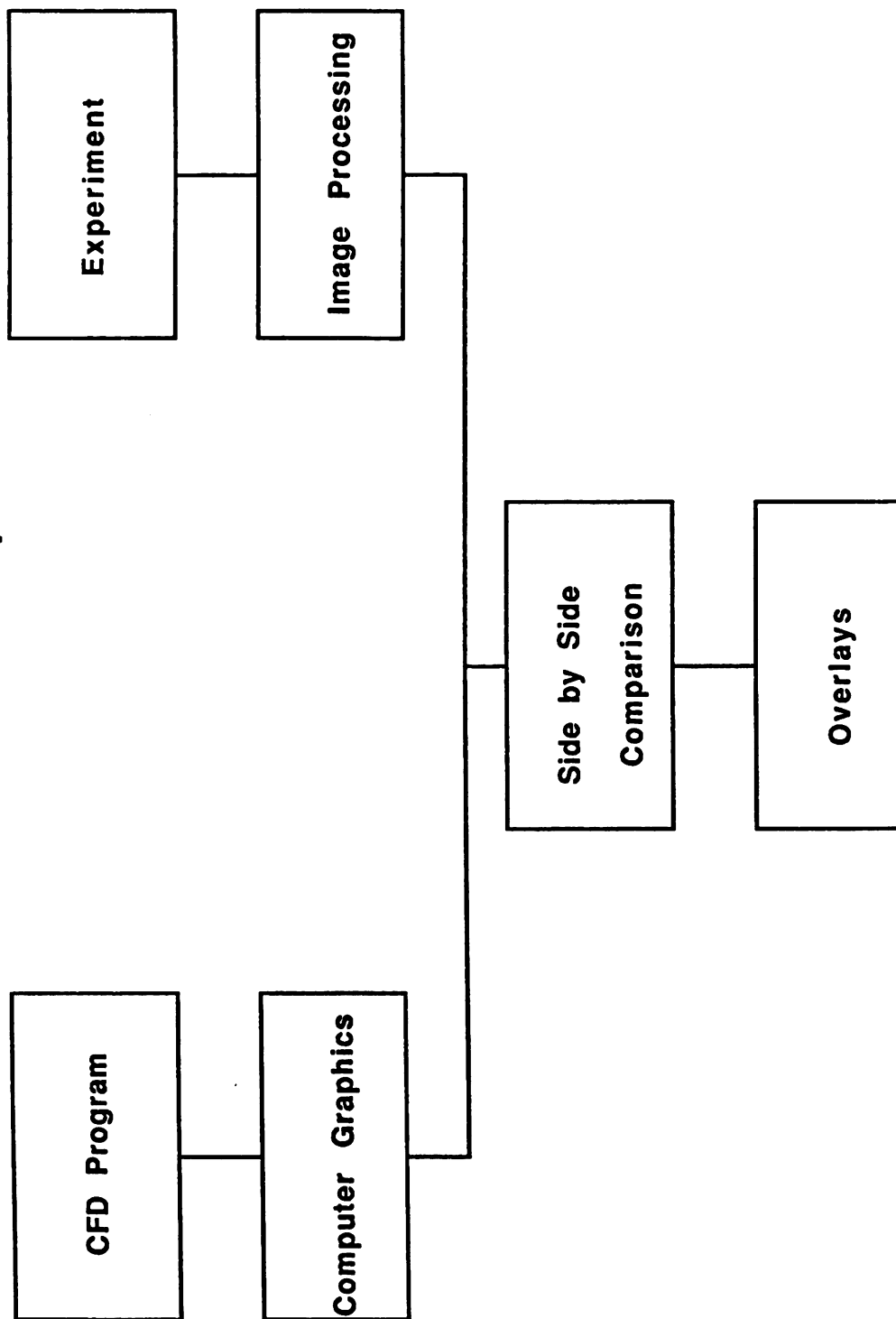
**DIRECTIVES TO A PRECOMPILER FOR LOOPS AND SEQUENTIAL CODE
PROVIDED BY CRAY RESEARCH BUT UNDEBUGGED AND FINE GRAIN**

COFORTRAN

**COROUTINES WITH BARRIER SYNCHRONIZATION
DEVELOPED AT ARC AND UNDER TEST BY ARC USERS**

BENCHMARK	S3640 IFU+FPA	TI Explorer	SUN-3	LMI 2x2	MicroVax II
01. BOYER	16.81	27.00	13.38	xxx.xx	xxx.xx
02. BROWSE	39.90	48.06	57.28		
03. CTAK	7.64	3.73	2.08		
04. DDERIV	6.74	11.82	5.60		
05. DERIV	6.26	11.82	4.26		
06. DESTRUCTIVE	3.17	3.63	2.56		
07. DIV2 ITER	3.37	4.23	1.68		
DIV2 RECUR	5.53	7.20	3.18		
08. FFT	3.57	21.79	77.66		
09. FPRINT	7.79	7.49	1.66		
10. FREAD	11.23	10.12	3.74		
11. FRPOLY r 10	0.46	0.91	0.62		
r 15	3.05	5.98	3.92		
r2 10	2.61	1.52	4.16		
r2 15	20.47	11.53	46.06		
r3 10	0.46	1.16	1.56		
r3 15	2.31	6.98	10.82		
12. PUZZLE	15.50	26.38	8.08		
13. STAK	2.57	5.05	2.72		
14. TAK	0.60	1.68	0.70		
15. TAKL	6.43	16.23	2.52		
16. TAKR	0.60	1.69	0.98		
17. TPRINT	11.35	8.52	1.96		
18. TRAVERSE-INIT	11.23	20.38	22.10		
TRAVERSE-RUN	50.12	129.59	82.82		
19. TRIANGLE	247.47	425.42	138.80		

Comparison of Computational and Experimental Results via Computer Graphics



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